THE BIOLOGIC AND ECONOMIC ASSESSMENT OF THE PESTICIDE ETHYLENE DIBROMIDE

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This report was prepared jointly by the

USDA/STATE/EPA

EDB Assessment Team

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USDA/STATE/EPA Cooperative Response to RPAR on EDB

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II. SUMMARY

INTRODUCTION

On December 14, 1977, a notice of Rebuttable Presumption Against Registration and Continued Registration (RPAR) of Pesticide Products Containing Ethylene Dibromide (EDB) was published in the Federal Register. This action was taken because the Environmental Protection Agency (EPA) concluded that evidence gathered by them indicated that EDB had exceeded the criteria for risk relating to oncogenicity, mutagenicity, and other chronic or toxic effects.

EDB is used as a soil fumigant to control parasitic nematodes in and on food and fiber crops grown in commercial agriculture; for quarantine treatment of fruits and vegetables; for fumigation of stored grains, grain milling machinery and flour mills, and for several other agricultural uses.

The purpose of this report is to evaluate the benefits and exposure to man, animals, non-target organisms, and the environment resulting from registered uses of EDB (1,2-dibromoethane or ethylene dibromide) as an agricultural pesticide.

GENERAL USAGE AND HISTORY

EDB has been used since 1925 as a lead scavenger for gasoline with commercial volumes exceeding 200 million pounds per year since 1954. It has

been used successfully for nearly 20 years as a soil fumigant, a commodity fumigant for fresh and stored agricultural products, a spot fumigant for flour mills and machinery, and several other pesticidal uses.

Data for 1977 indicates approximately 2 percent of the total EDB production, or 5.6 million pounds was applied as pesticides. Soil fumigant uses accounted for 4.4 million pounds, grain bin fumigation 675,000 pounds, spot fumigation in flour mills 400,000 pounds, commodity quarantine fumigation 80,000 pounds, and beehive treatments 20,000 pounds (296). It is estimated that slightly less than 15 million pounds were used in 1978 for pesticidal purposes. This is a marked increase over the amount used annually during the years prior to 1978. This difference is due to the 1977 EPA decision to suspend use of DBCP on vegetables and peanuts, and the resultant shift to EDB as an alternative nematicide. There are 122 federal pesticide registrations and 24 State registrations of products containing EDB as an active ingredient.

SCOPE AND APPROACH OF THE ANALYSIS

The analysis of the principle uses of EDB corresponds with the specifications and requirements for economic impact analysis published by EPA in the Federal Register on May 25, 1976, 41 Fed. Reg. 21402. In accordance with this notice, this analysis identifies the major and minor uses of EDB, estimates the quantities used where possible, lists the registered alternatives and their availability, determines changes in pesticide costs associated with the use of these alternatives, and evaluates the regulatory impact on crop production and retail prices where possible. Pursuant to a Memorandum of Understanding between the two agencies, this report has been jointly prepred by the Environmental Protection Agency and the U.S. Department of Agriculture.

Table II-1. Estimated 1978 U.S. usage of ethylene dibromide by use site. a/

Use site	Usage	
	Units treated	Thousand pounds appli
Tobacco	77,600 acres	2,065.0
Pineapple	11,500 acres	572.4
Citrus		
A. Preplant	100 acres	20.0
B. Burrowing nematode containment	420 acres	252.0
Peaches	2,000 acres	170.0
Forestry	68,000 trees	20.0
Termites	12,400 structures	20.0
Grain storage	125.7 to 392.0 mil. bu.	630.0
Flour milling	391 mills	465.0
Quarantine (APHIS)	494.5 lbs.	83.5
Peanuts	257,390 acres	4,197.4
Cotton	55,600 acres	721.8
Vegetables	180,000 acres	5,600.0
Honeycombs	5,679,000 supers	20.0
Total		14,837.1

a/ Usage estimates are from the respective sections of this report.

In addition to the specifications for economic impact analysis which appear in the Federal Register, EPA thoroughly reviewed all rebuttal comments for fundamental information needed to form an economic impact analysis of EDB on a site/pest basis. These fundamental data (e.g., acres infested, acres damaged, acres treated, loss on acres treated, loss expected with the use of next best alternative, etc.) were often not reported or were not reported in a useable manner. In an attempt to clarify rebuttable comments and to derive the fundamental data base needed to quantify the benefits of EDB use, EPA and USDA contacted various individuals in the USDA, Cooperative Extension Services, State Agricultural Experiment Stations, State Departments of Agriculture, County Agricultural Commissioners, and other sources.

After this thorough review of rebuttal comments and subsequently obtained data, it became obvious that data sufficiently detailed to prepare a thorough benefit analysis of EDB on a site/pest basis are quite scarce. Data on many minor sites and on specific pests are often unavailable. As a result, the analysis herein presented often relies on various estimates provided by experts intimately knowledgeable about the use of EDB on various sites. An analysis stemming from these experts' estimates is obviously less desirable than one conducted with the availability of scientifically validated field tests. In the absence of such precise data, however, expert opinion can shed considerable light on the benefits of EDB and was fully utilized.

SUMMARY OF FINDINGS

Cancellation of EDB registrations would result in losses ranging from \$57.8 million to \$62.7 million (Table II-2). This represents losses due to both increased cost of treatment and for those crops so impacted, decreased value of production.

Table II-2. Overall summary of the short-run economic impact of an ethylene dibromide cancellation for 1978.

Use sites	Extent of use: Units treated	Increased cost of treatment	Decrease in value of production	Total economic impact	Balance of payment impact j/
		thousand dollars			
Tobacco a/	77,600 acres	1,200.0	0	1,200.0	
Pineapple b/	11,500 acres	281.5	1,218.5	1,500.0	
Citrus c/					
A. Preplant	100 acres	3.5	0	3.5	
B. Burrowing nematode containment	420 acres	44.0	0	44.0	
Peaches d/	2,000 acres	70.6	0	70.6	
Forestry e/	68,000 trees	-7.4 to 15.8	0	-7.4 to 15.8	
Termites f/	12,400 structures	unknown			
Grain storage g/	125.7 to 392.0 mil. bu.	-2,258.0 to -500.0	0	-2,258.0 to -500	
Flour milling h/	391 mills	4,000.0 to 7,700.0	0	4,600.0 to 7,700.0	
Quarantine (APHIS) i/	494.5 mil. lbs.	538.9	24,164.0	24,702.9	18,384.0
Peanuts k/	257,390 acres	2,500.0	11,000.0	13,500.0	
Cotton l/	55,600 acres	435.7	0	435.7	
Vegetables m/	180,000 acres	3,800.0	0	3,800.0	
Honey combs n/	5,679,000 supers	3,686.2	6,500.0	10,186.2	
Total		14,895.0 to 19,776.2	42,882.5	57,777.5 to 62,658.7	18,384.0

a/ Chapter III.
b/ Chapter IV.
c/ Chapter V.
d/ Chapter VI.
e/ Chapter VII.
f/ Chapter VIII.
g/ "Economic Impacts of Cancellation of Registration of Ethylene Dibromide for Use in Fumigation of Grain Storage", Report prepared by Development Planning and Research Associates, Inc. for USEPA, November 1978.
h/ "Economic Impacts of Cancellation of Registration of Ethylene Dibromide for Use in Spot Fumigation of Flour Mills", Report prepared by Development Planning and Research Associates, Inc. for USEPA, November 1978.
i/ Tables XI-1, XI-4, and XI-5.
j/ Table XI-6.
k/ Table XII-1.
l/ Table XIII-1.
m/ Tables XIV-1 and XIV-3.
n/ Table XV-4 and text.

In dollar terms, the largest single impact of EDB cancellation would occur in the APHIS and state quarantine programs, where shippers and producers would be negatively impacted by approximately $24.1 million per year. In addition the U.S. balance of payments would be reduced by approximately $18.4 million. If EDB were unavailable for use with quarantine programs, U.S. markets would have to absorb an additional 300 million pounds of grapefruit or about 13 percent of domestic fresh production. This would result in decreased returns to domestic producers of $29.4 million due to higher prices. Papaya and mango producers could realize income gains of $2.6 million and $4.7 million respectively due to higher prices. Importers and interstate shippers of other fruits and vegetables would have losses of approximately $2.0 million. In the short run, the consumer would be expected to benefit from price decreases for grapefruit and loss from price increases for papayas and mangoes. Producers and shippers of miscellaneous fruits and vegetables probably would absorb the $2.0 million loss and not pass it directly on to the consumer.

Peanut producers would have negative impacts of $13.5 million. Nematode control costs would increase by $2.5 million while the value of production would decrease by $11.0 million. Beehive owners would have negative impacts of $10.2 million of which cost increases account for $3.7 million and production losses for $6.5 million. Vegetable producers would have nematode control cost increases of $3.8 million. Other nematode control programs would have smaller cost increases and limited production losses.

The grain storage area estimates indicated decreased costs for both on-farm and off-farm storage. EDB is used on-farms due to ease of application and efficacy in controlling surface insect infestations. For off-farm use, alternatives are as effective and are preferred.

EDB is the most economical, effective, and suitable spot fumigant for use in control of insects in flour milling machinery. Without EDB millers would be forced to utilize either methyl bromide or aluminum phosphide as general space fumigants of the entire plant. Control costs could increase by $4.6 million to $7.7 million annually.

The estimated impacts of a loss of EDB for termite control and forestry are limited because of lack of data availability. EDB is the only registered chemical for termite control under slabs of homes when the location of the termites is uncertain. The impacts on those homeowners, under whose homes EDB is used, was not estimated. For forestry uses, one currently registered alternative (lindane) to EDB is also under RPAR review. The other registered alternative (endosulfan) is not currently used because it is not as effective as lindane or EDB for pine bark beetle control. While these latter impacts have not been estimated, the cancellation of EDB use for these purposes could result in a significantly greater overall impact than is currently estimated.

RPAR TRIGGERS

The rebuttable presumption is based on three triggers. 1) Oncogenicity- EDB is presumed to be a cancer risk based on a National Cancer Institute (NCI) study conducted by Hazelton Laboratories on rats and mice between 1972 and 1974. EDB was administered by intubation into the stomach and squamous-cell carcinomas were reported (162, 170, 287). 2) Mutagenicity- This trigger was presumed to be exceeded through evidence from studies on Salmonella typhimurium, Neurospora crassa, Drosophila melanogaster, mouse lymphoma cell culture, Tradescantia mutable clones, barley, Opossum lymphocytes, Saccharomyces cereuisiae, Escherichia coli and Serratia marcescens. Various mutations and chromosomal damage were reported (29, 35, 47, 64, 66, 126, 130, 146,

201, 202, 283). 3) Reproductive Effects: - Several studies primarily conducted in Israel on bulls, cows, sheep, and rodents, indicate that EDB may adversely affect mammalian reproduction by interfering with the production of male gametes and with the development of embroyos (6, 28, 62, 193).

These studies and their application to human exposure have been judged by EPA to be sufficient to issue an RPAR on EDB. The human exposure analyses used in the trigger evaluation were made on citrus fumigation applications which have already been drastically changed (77, 141).

POTENTIAL EXPOSURE

Although methods of application vary depending upon requirements, it appears possible to avoid human and animal exposure to EDB by following regulations which are prescribed for each situation. In indoor situations an approved gas mask is nearly always required, and in cases where a coarse spray is employed protective clothing must also be used. The possibility of minimal exposure under certain situations may occur, but workers need not be involved with daily applications. In most cases several weeks or months may pass with no treatments applied.

Grain Bin Fumigation

Approved respirators are required during application of EDB and in preparation for or during aeration of the bins following fumigation. Human exposure is therefore minimized. In cases where EDB is applied as a coarse spray suitable protective clothing must be used.

Spot Fumigation in Flour Mills

A fumigation crew wearing approved respirators applies the fumigant. The equipment or area to be treated is enclosed in gas-impervious plastic sheets which have been properly placed and secured. Built-in fittings are utilized to attach the fumigant dispenser, with the fumigant introduced at the top of the area under the plastic tarpaulin. The fumigant is introduced after all personnel, other than the fumigation crew, have left the building. After the fumigant is applied the doors are locked to prevent unauthorized entry. The operation is done on the weekend so that a 24 hour treatment may be accomplished.

The fumigation crew will open the building several hours before operating personnel report for work. Adequate fans are used to exhaust the fumigant from the building. The indoor use of spot fumigants, such as EDB, does not endanger wildlife or aquatic forms. Spot fumigation is often done every 3-4 weeks. The primary alternative to spot fumigation is fumigation of the entire mill or elevator. Such a procedure would generally be considered more hazardous because larger volumes of fumigants would be involved. A greatly increased cost is also incurred.

Quarantine Treatments

EDB quarantine treatments are carried out in gas - tight fumigation chambers. The fumigation is conducted by professional personnel trained according to provisions outlined by APHIS Quarantine Manuals and labeling. As indicated in the following discussion, the highest amount of EDB measured after treatment was 1.95 ppm in citrus fumigation facilities in Florida. OSHA regulations have been given as 20 ppm (275). A closed system application provides

minimum or no exposure to workers.

Bark Beetles on Conifers

Two types of application methods require certain differences in protective devices and procedures. First, a coarse spray application to felled logs is applied outdoors. The user should wear appropriate protective gear to avoid contact with eyes or skin. Workers should also avoid breathing vapor. Second, application is made to stacked logs covered with plastic sheeting (129). The logs may remain under the tarpaulin for several weeks, with the tarpaulin being removed at the end of treatment and the operator using an appropriate respirator to avoid exposure at that time.

Soil Fumigation

Pre-planting applications are made by introducing the EDB about 8-12 inches below the surface. Numerous crops are involved including tobacco, pineapple, potatoes, cotton, citrus, other fruit tree plantings and various vegetable crops. The primary method of application involves infrequent minimal contact with EDB by the operator because the fumigant is released by chisel application below the surface of the soil and the soil is covered or rolled after application. Use of a respirator is recommended while loading the fumigant. Treatment to a given cropping field is usually limited to a single application for the season.

Exposure Studies

The present Federal standard for EDB exposure is 20 ppm as an 8-hour time-weighted-average (TWA) limit with a 30 ppm ceiling concentration and a peak concentration of 50 ppm for five minutes (275). The National Institute for

Occupational Safety and Health (NIOSH) has recommended that the occupational exposure limit for EDB be reduced to a ceiling concentration of 1.0 mg/m^3 (0.13 ppm) for any 15 minute sampling period (276). This level has not yet been accepted and several presentations have been made advocating a level of 1.3 ppm (10 mg/m^3) or 5 ppm (65 mg/m^3) as a safe TWA standard (65, 86).

There are no tolerances for EDB per se in or on raw agricultural products because it was concluded on the basis of data originally submitted that no EDB residues would result. Tolerances have been established for inorganic bromide residues in 40 CFR 180. An exemption from tolerance for residues of organic bromide from post-harvest fumigation with EDB is in 40 CFR 180.1006 for barley, corn, oats, popcorn, rice, rye, sorghum (milo), and wheat. Listed below are exposure factors for workers and consumers from various studies.

a. Ambient air levels encountered in soil fumigation situations of 0.10 to 0.69 ppm of EDB were measured in EPA exposure studies in 1977. Concentrations of 0.033 to 1.168 ppm were measured in the vicinity of citrus fumigation facilities and warehouses (77).

b. Residues of EDB of 10-15 ppm were found in fumigated oats used as chicken feed several weeks after fumigation (45).

c. A group of Israeli scientists found residues of 1-43 ppm in citrus peel and 0.4-2.4 ppm in citrus pulp at four days post-fumigation (5, 36, 46, 47). In one study residues in both peel and pulp dissipated completely in less than two weeks (36).

d. Wit, et al., (1969), measured 5-30 ppm EDB in whole wheat, 2-4 ppm in the flour milled from this wheat, and 18-23 ppm in the "shorts" and bran. White bread baked from the flour showed EDB residues of 0.002-0.04 ppm (303).

e. Detoxification mechanisms for EDB in mammals involve glutathione-EDB reactions in vivo (rat liver microsomes and rat kidney). The end results are ethylene, bromine (Br) and mercapturic acid reaction products. In spite of this detoxification capability, the fates of these intermediates in mammalian metabolism are not known at this time (145).

f. EDB has been reported to be non-persistent when used as recommended and is not detectable in fumigated soils after two months (44, 227). In the same report EDB is cited as causing only temporary inhibition of beneficial fungi, and as having no adverse effects on nutritive values of crops.

g. Irrigation following soil fumigation with EDB reduced total Br residues in a washing or solubilizing effect (75). Further, very low amounts of Br are present in non-chlorophyll-containing parts such as fruits, and residues of 30-50 ppm of Br found in the soil, an acceptable range, are associated with an assumed dietary intake of 0.3 mg/kg per day, an acceptable level.

h. No adverse effects were found on the nutritional components of citrus, carrots, or lima beans, grown in EDB treated soil. The only significant change was an increase in beta-carotene content. Beta-carotene is a precursor of vitamin A (227).

FATE IN THE ENVIRONMENT

EDB is converted to ethylene and ionic inorganic bromides in soil and the atmosphere through hydrolysis, photolysis, and biodehalogenation (44, 227). The largest volume of pesticidal EDB is applied into the soil. The presence of adequate soil moisture, organic matter, and various soil organisms in treated soil and the resulting hydrolysis and biological dehalogenation

account for its degradation in the soil environment. The EDB present in soil is converted almost completely and quantitively to ethylene and bromide ions in about two months (44). This rapid degradation in the soil ecosystem may account for the absence of EDB in plants grown in EDB treated soil. Studies by Litton Bionetics of 15 crops from soils treated with EDB showed no detectable amounts of organic EDB. In the same study background interference precluded definitive determination of the fumigant in two other crops (87).

EDB is ordinarily exhausted to the atmosphere in commodity fumigation, grain bin, and spot fumigation applications. In these cases dilution in the atmosphere is rapid and concentrations drop below measurable levels within short distances. In an EPA study in 1977 no measureable amounts of EDB were found in ambient air samples in the vicinity of citrus fumigation chambers (141). A previous study did show low levels (up to .125 ppm) in the air downwind of a similar facility (77).

EDB degrades in the atmospheric and aquatic environments with estimated half lives of 100 days and 5-10 days. No appreciable environmental accumulation would be expected (99).

SOIL FUMIGANT USES:

Parasitic and beneficial plant nematodes occur naturally in all soils. When diverse natural vegetation occupies a site, the nematode population remains at a relatively steady state. However, establishment of an agricultural cropping system promotes the rapid increase of endemic pathogenic species, and nonendemic species that may be inadvertently introduced can quickly establish dominance. Factors that favor good plant growth and high crop

yields also provide optimal conditions for nematode development. Thus, soil conditions, climatic variation, irrigation, fertilization, and cultivation can limit yield simply because they promote nematode development. Because plant nematodes are obligate plant parasites, population densities are governed chiefly by the plant component of the agricultural system. A variety of control methods is available but effectiveness of the methods differs depending on nematode populations (number of species and composition), crop and soil conditions.

Nematode losses on all crops were estimated at 11 percent in 1970 by the Society of Nematologists. Because of the high cost of nematicide application, these chemicals are used almost exclusively to protect high value crops where nematode losses are severe and alternative control methods have failed or are ineffective.

Nematicides are a highly effective and reliable means of controlling a wide variety of nematodes. Approximately two million acres are treated with nematicides in the United States each year. These chemicals are used principally in the production of tobacco, peanuts, cotton, soybeans, sugarbeets, fruit and vineyard crops, potatoes, vegetables, and turf and ornamentals.

Based on the available information, most soil fumigants do not persist in the soil and have no lasting adverse effects on the physical and biological properties of soil, or on the nutritional value of crops grown in treated soil. Nematicides degrade by physical, chemical, and biological processes. Recent tests do not indicate organic EDB residues in the crops tested.

It should be noted that soil fumigants, especially those containing chlorine and bromine, can temporarily upset the normal soil nitrification process, which results in increased ammonia accumulation in soil and increased uptake of bromine or chlorine by some plants. The nitrification lag in soil

following treatment can be eliminated or minimized by proper timing of chemical application and by maintaining soil pH near neutrality.

Monocultures usually increase crop losses caused by nematodes, and nematicides are used to maintain profitable production. Generally, nematicides are used only after it has been determined that nematodes will cause significant economic losses. Except for severe loss situations, nonchemical means of control are generally used by farmers.

The most common of the non-chemical control methods for annual crops is crop rotation. Plant parasitic nematodes are obligate parasites; they cannot reproduce unless they can feed on susceptible plants. They are specialized parasites; each nematode species has certain species of plants on which it can reproduce and other plant species on which it cannot reproduce, "susceptible" and "immune" plants, respectively. Soil populations increase on susceptible plants very rapidly, and decrease on immune plants very slowly. But it is often possible to rotate a profitable principal crop with an immune crop and so reduce the nematode population sufficiently so that the principal crop is not severely damaged when it is again grown. The interval between profitable principal crops may be one to four years.

Selection of alternate crops for a nematode-reducing rotation is difficult. The crop must be nearly immune to the nematode species which is most damaging to the principal crop. In addition, since crops are always attacked by more than one nematode, it must not permit the increase of secondary damaging nematode populations.

Chemical control of nematodes is simple, effective and profitable. Control by other methods can be complicated, uncertain, and not always profitable.

In practice, there are few situations where a nematicide is used, where farmers could implement effective crop rotations because of acreage limitations

of some crops, or for economic reasons. In most situations, crop rotation is not an economically suitable alternative to EDB use.

Resistant varieties are the least costly and often the only practical method of managing some nematode species. Resistant varieties prevent excessive crop damage and also reduce population densities of nematode species so that there is less likelihood of excessive damage to susceptible crops that may follow in a rotational scheme. For low value crops, use of resistant varieties is often the only practical nematode management method because of the high cost of nematicides. However, varieties of acceptable market quality which are well adapted to varying regional conditions are available for very few crops.

New races of some pathogenic nematode species overcome the resistance of the host crop. Such cases limit the usefulness of the resistant variety. When a new nematode pathotype develops, use of the now susceptible variety must be discontinued quickly to reduce the potential for building up the nematode population.

Biological control of nematodes by introduction or conservation of natural enemies is not yet practical. However, numerous naturally occurring microorganisms attack nematodes, and their activities can be encouraged by soil and crop management practices. The effectiveness of natural enemies in controlling nematodes is usually regulated by the amount of organic matter in the soil. A high level of organic matter in the soil reduces parasitic nematode populations because populations of nematode parasites and nematode trapping fungi are increased. In addition, some by-products produced during the decomposition of organic matter are toxic to nematodes. Biological decomposition of sawdust, chitinn, bagasse, hay, crop stubble, activated

sewage sludge, and other organic soil amendments aids in preventing the buildup of high nematode populations. Use of these materials is limited by available supplies in many areas because 10 tons per acre, or more, of organic matter must be incorporated into soil to achieve any appreciable nematode control.

Integrated nematode control programs are just beginning to be implemented. Cost of sampling nematode populations is high, $4-10 per acre depending on the crop. Integrated nematode practices are not highly effective or are unavailable for perennial crops. Resistant varieties and crop rotations are often species specific and have limited value, except in special situations. The highest degree of nematode control can be obtained on annual crops by using crop rotations, resistant varieties, nematicides, and other management practices. No single method of control is as effective as the integrated management approach. This approach is not always practical because of economics and lack of trained farmer-advisors and diagnostic facilities. In most situations where nematicides are used a high degree of nematode control cannot be achieved without the use of a nematicide such as EDB.

It should be emphasized that crop rotation is not possible with perennial crops such as orchards, vineyards, and citrus groves. Control of nematodes on perennials must start with clean planting stock and nematode free soil. Nurseries must have nematode-free soil to produce clean planting stock, and the only way to achieve this is by use of nematicides.

EDB is used for soil sterilization of seed beds, nursery plots, and greenhouse and potting soil. The State of Wisconsin requires EDB treatment for certain fields infested with the potato rot nematode, *Ditylenchus destructor* and the Federal Japanese Beetle domestic quarantine requires the treatment of regulated articles moving out of the regulated area in a quarantined state. These applications use very small amounts of EDB on an occassional basis.

Chemical and Physical Properties:

Commmon Name:	Ethylene dibromide.
Chemical Name:	1,2- Dibromoethane.
Formula:	H_2CBrH_2CBr.
Trade Names:	EDB, S-T-D, Larvatox "431", Rotox, Zytox, Soilbrom 40, Soilbrom 85, Soilbrom 90EC, Terr-O-Gel 50, Terr-O-Gel 68, Terr-O-Cide 15, Terr-O-Cide 30, Terr-O-Cide 93.5, E-D-Bee, Dowfume 40, Dowfume MC-2, W85, Dawson 73, WACO 50, Dow EB 59, and many others.
Action:	Fumigant (insecticide, nematicide) anti-knock agent.
Boiling Point:	131.7 degrees C.
Specific Gravity:	at 25 degrees C, 2.172
Lbs/gal:	18.07 at 25 degrees C.
Freezing Point:	9.3 degrees C.
Vapor Pressure:	17.4 mmHg at 30 degrees C.
Specific Heat:	0.18 B.T.U./lb/degree F.
Flash Point:	None.
Latent Heat of Vaporization at b.p:	46.2 cal/g.
Molecular Weight:	187.88
B.T.U./lb:	83.2
Appearance	Colorless Liquid
Solubility:	0.43 grams/100 grams water 25 degees C. Readily soluble in all common organic solvents.

Application: Ethylene dibromide is mixed with an inert solvent for soil application; mixtures with carbon tetrachloride and ethylene dichloride and other chemicals are used for mill, warehouse or household fumigation.

TOXICOLOGICAL CONSIDERATIONS

Acute oral toxicity:

Mice (F)--420 mg/kg

Rats (M)--148 mg/kg

Rats (F)--117 mg/kg

Guinea pigs---110 mg/kg

Chicks--79 mg/kg

Rabbits (F)---55 mg/kg (122).

ODOR THRESHOLD

The odor is detectable at 10-25 ppm.

MANUFACTURERS:

EDB is manufactured near the natural salt brines of Michigan and Arkansas by Great Lakes Chemical Corporation, P.P.G. Industries, Ethyl Corporation, and Dow Chemical Company. It is produced by simple addition of elemental bromide to ethylene, followed by a purification step.

III. ANALYSIS OF EDB USE ON FLUE-CURED TOBACCO FIELDS

INTRODUCTION

EDB is used for root-knot, root-lesion, and stunt nematode control in Florida, Georgia, North Carolina, South Carolina, and Virginia (49, 72, 76, 132, 273, 281). No data are available regarding the chemical's use in Alabama. Any one of these, if present in the soil in large numbers, can reduce the value of the crop by reducing both yield and quality.

In 1977, 590,080 acres of flue-cured tobacco were harvested in the United States (Table III-1). North Carolina, the largest flue-cured tobacco producing State, accounted for 64.9 percent of the total or 383,000 acres. The next largest, South Carolina, accounted for 11.5 percent or 68,000 acres. Georgia and Virginia follow with 65,000 acres (11.0 percent) and 61,000 acres (10.3 percent), respectively. The smallest flue-cured tobacco producing States, Florida and Alabama, accounted for less than five percent of the total U.S. acreage.

The tobacco root-knot nematode, *Meloidogyne incognita,* causes the formation of galls or swellings on the roots of the tobacco plant. It is considered the most serious of the three. It is believed to be present to some degree on nearly every farm in North Carolina where flue-cured tobacco is grown. It is also present (on many farms) in some of the counties in North Carolina where burley tobacco is grown.

Table III-1. Industry profile of the flue-cured tobacco producing states and estimated EDB usage, 1977

Item	States						Total
	AL	FL	GA	NC	SC	VA	
Acreage harvested a/	580	12,500	65,000	383,000	68,000	61,000	590,08[illegible]
Production (1,000 pounds) a/	1,102	25,000	134,875	718,435	138,380	109,495	1,127.287
Estimated EDB treated acreage b/	ND	3,875	10,000	53,414	10,000	311	77,600
Percent of total acreage treated	ND	31.0	15.4	13.9	14.7	0.5	13.[illegible]
Pounds (a.i.) of EDB applied c/	ND	104,625	270,000	1,408,233	270,000	12,673	2,065,531
Percent of total pounds	—	5.1	13.1	68.1	13.1	0.6	[illegible]00

ND = no data available.

a/ Crop Production, 1977 Annual Summary, 1978, USDA, ESCS, CrPr 2-1 (78).

b/ Based on Information Provided by J.R. Rich (181), J.J. Riley (171) and in the reference cited in footnote 2 above.

c/ EDB is applied at a rate of 27 pounds, a.i. per acre in FL, GA, NC and S.C. and at a rate of 41 pounds a.i. per acre in VA.

The meadow or root-lesion nematode, Pratylenchus spp., causes a girdling of the roots rather than the formation of galls or swellings. As a result of this girdling, brown lesions appear on larger roots, and a high percentage of the fibrous roots slough off. If the meadow nematode attack is severe, the result is a restricted, "bunchy" root system. It is believed that the meadow nematode is present on about 60 percent of North Carolina tobacco farms. At the present time, there are four known species of this nematode that attack tobacco. All four species are considered important.

The stunt nematode, Tylenchorhynchus spp., causes a stunting of root growth. In fact, the root system from an infected plant appears healthy, except that it is reduced in size. This nematode was found in North Carolina for the first time in 1953, although it probably has been present for a long time. From information available on the distribution of this nematode in North Carolina, it is believed to be present on about 40 percent of the farms.

All three nematode species multiply rapidly when the land is planted with a nematode susceptible crop like tobacco. For example, during the summer months the female root-knot nematode lays about 300 to 500 eggs and completes the life cycle from egg to adult in 20 to 30 days. Meadow and stunt nematodes do not multiply quite as fast as root-knot nematodes. The female meadow and stunt nematodes lay fewer eggs and require slightly longer to complete the life cycle (225).

In addition to crop losses directly attributed to these nematodes, root-knot and lesion are involved in the wilt-nematode disease complex of tobacco.

EDB Usage

Approximately 2.1 million pounds active ingredient of EDB were used in the United States on flue-cured tobacco in 1977. EDB is usually applied at the rate of 2.25 gallons per acre (12 lbs a.i. per gallon) (Table III-1). The largest percentage of this (1,408,233 lbs a.i. or 68 percent) was used by North Carolina growers. Georgia and South Carolina 270,000 pounds or 13.1 percent each, with Florida (104,625 lbs a.i. or 5.1 percent) and Virginia (12,673 lbs a.i. or 0.6 percent) following.

EDB and EDB + chloropicrin mixtures are applied in March or April by injecting into the soil 8 inches below the soil level or 14 inches below the top of a high wide bed with a gravity flow disk hiller 3 weeks prior to transplanting.

Alternatives

Additional chemicals used for control of these nematodes include other fumigants (D-D and Telone II), multipurpose fumigants (Terr-O-Cide 15 and 30, Telone C17, and Vorlex) and non-fumigants (ethoprop, fensulfothion, carbofuran, and oxamyl). All of the aforementioned States recommend, in addition to EDB, the use of other fumigants such as Telone II or D-D. The EDB Assessment Team predicted that for tobacco, D-D would replace EDB and Telone II would be used little if at all. Only four of the States recommend multipurpose fumigants (North Carolina and Florida recommend

Vorlex).

The most northern flue-cured tobacco producing States (North Carolina, South Carolina, and Virginia) recommend carbofuran and oxamyl since these chemicals are effective for low nematode population levels (49, 13, 154, 281). Moderate levels of nematode infestation may be controlled using ethoprop or fensulfothion (76). Non-fumigant nematicides are not recommended for nematode control in Florida (172).

The practice of planting tobacco in the same field year after year permits the buildup of pathogenic agents. Growers using this system must give careful consideration to the selection of varieties with high resistance to the major nematodes present. Non-fumigant or fumigant nematicides should be used, and varieties with low to moderate resistance should be avoided in fields where continuous culture is practiced. Rotation with resistant crops is a potential alternative to EDB use. Crop rotation is suggested for all farms where adequate land is available. This practice also permits the reduction of many nematode species and is highly recommended. Rotation is a "must" for fields where the nematode level is high since combinations are not available that provide adequate protection unless this practice is followed.

Results from crop rotation tests conducted in Greene, Halifax, Lenoir, and Warren counties (North Carolina), suggest that continuous culture plus multipurpose treatment is equal or superior to rotation in nematode control and performance for fields where the disease level is low to moderate. Rotations involving one alternate crop reduced nematode incidence and increased performance as compared with continuous culture.

Consideration of the average value of the crops produced over a two year period seems to imply that rotation is not economically sound. However, producers usually rotate crops now by shifting crops to different areas of their farm and therefore do not lose any tobacco production. In areas of high nematode incidence crop rotation does not provide adequate nematode control.

Nematodes cannot be eliminated from a field and nematicides cannot provide complete and permanent control (72, 76). An integrated control program involving cultural practices (rotation, setting healthy transplants, and early root and stalk destruction) and use of nematicides should be most effective in giving "the highest economic return" (76).

Florida, the southernmost flue-cured tobacco producing State, recommends only fumigants and multi-purpose fumigants for nematode control because "they have performed more consistently than non-fumigants" (72).

The Georgia Cooperative Extension Service indicates that (compared to non-fumigants) fumigants and multi-purpose fumigants will control high population levels (3,000 + per pint of soil sampled) of the root-knot nematode. The multi-purpose fumigants "are combinations of nematicides, soil fungicides, and bactericides, and therefore, provide control of several diseases and nematodes including root-knot, black shank, Granville wilt, Fusarium wilt, and black root rot" (152). Ethoprop is the only non-fumigant which will control moderate population levels (1,000-3,000 per pint) of the aforementioned nematodes. The remaining recommended non-fumigants (fensulfothion, carbofuran, and oxamyl) will control only low population levels (200-1,000 per pint) of these nematodes (154).

Growers switching from EDB to other fumigants or from multi-purpose formulations containing EDB to other multi-purpose formulations without EDB will not experience a significant change in yield regardless of the nematode population level (8, 112, 181, 298). Under most conditions (except low nematode population levels), yield reductions are expected to occur if growers switch from a fumigant to a non-fumigant assuming no change in cultural practices (8, 112, 181, 298).

ECONOMIC IMPACT ANALYSIS

The most commonly available fumigants to replace EDB are D-D and Telone II. Chemical cost per acre per season using EDB is $16.54 (Table III-2). D-D and Telone II cost $37.60 and $35.28 per acre respectively. EDB plus chlorpicrin (Terr-O-Cide 15 or 30) costs $56.40 per acre per season while Telone C17 costs $67.73 per acre per season.

Table III-2. Treatment cost using EDB and alternatives for nematode control in the Southeastern United States as estimated for 1978

Chemical and formulation	Recommended application rate per acre per season a/	Chemical cost per gallon b/	Chemical cost per acre per season
	gallons	dollars	
EDB (Soilbrom W-85)	2.25	7.35	16.54
D-D	10	3.76	37.60
Telone II	6	5.88	35.28
Telone C17	10.5	6.45	67.73
Terr-O-Cide 15 or 30 (EDB + chloropicrin)	6	9.40	56.40
Vorlex	5	9.60	48.00

a/ Based upon those application rates reported in the 1978 North Carolina Agricultural Chemicals Manual.

b/ Cost of:

EDB: $7.35 per gallon; average of Woolfolk Chemical Works, Inc., $6.50 per gallon and Woodbury Chemical Corporation - $8.20 per gallon.

D-D: $3.76 per gallon; average of Woolfolk Chemical Works - $3.70 per gallon and Asgrow Florida Company - $3.81 per gallon, 1978.

Telone II: $5.88 per gallon; average of Asgrow Florida Company $6.20 per gallon and Woolfolk Chemical Works - $5.51 per gallon, 1978.

Telone C17: $6.45 per gallon; J. Burke, Cardinal Chemical Company, 1978.

Terr-O-Cide 30: $9.40 per gallon; J. Burke, Cardinal Chemical Company, 1978.

Vorlex: $9.60 per gallon; Asgrow Florida Company, 1978.

Vorlex costs $48.00 per acre per season. For this analysis, it was assumed that the price of alternative fumigants would not change, however, the pesticide supply and demand situation in the various flue-cured tobacco producing States may vary if EDB use is cancelled and have an impact on fumigant prices.

The total change in chemical costs to growers currently using EDB is expected to increase approximately $1.2 million (Table III-3). Given the average change in total nematicide cost per acre across all flue-cured tobacco producing States of $15.36, total costs of production per acre are expected to increase 1.2 percent from $1,290 to about $1,306 Total variable operating costs are expected to increase 2.5 percent from $625 to $640.1/ As shown in Table III-3, nematicide costs for growers replacing EDB with other fumigants will increase $21.06 per acre or $676,006 on 32,099 acres of flue-cured tobacco.

Production costs to North Carolina growers substituting another multi-purpose fumigant (Telone C17) for EDB multi-purpose fumigants are expected to increase $515,527 when growers switch to Telone C17 on fields currently treated with EDB plus chloropicrin (Terro-O-Cide 30 or Terr-O-Cide 15). No data are available indicating the use of the chemicals (Terr-O-Cide 15

1/ Based upon a 1977 North Carolina flue-cured tobacco production budget is for a 25-acre farm. Total costs of production are defined as total operating cost, total interest charge, total ownership cost and total labor cost.

Table III-3. Economic impact to growers using EDB alternatives for nematode control in the Southeastern United States as estimated for 1978

Nematode control scheme	State	Acres treated a/	Total increase in nematode cost per acre b/	Increase in nematode costs
		acres	dols.	dols.
EDB to D-D	Florida	3,875		81,608
	Georgia	10,000		210,600
	North Carolina	7,913	21.06	166,648
	South Carolina	10,000		210,600
	Virginia	311		6,550
		32,099		676,006
Telone C17 to EDB + Chloropicrin (Terr-O-Cide 30; or Terr-O-Cide 15)	North Carolina	45,501	11.33	515,527
Total		77,600	15.36	1,191,533

a/ Table III-1. Distribution in North Carolina was provided by the EDB Assessment Team, and assumed to be the same for 1978.
b/ Table III-2.

and Terr-O-Cide 30) and EDB alternatives in other flue-cured tobacco producing States.

The long-run economic user impacts are expected to be slight; however, the impact on users in the short-run transitional period may have a significant impact. The tobacco price support program is based on using a three-year moving average parity index formula. This means price supports rise more slowly during periods of rapid input cost increases. Any increase in the costs of production due to a change in the chemical costs will be only partially reflected during the first year. Not until the third year will costs of production be fully reflected in the support price.

Market and Consumer Impacts

Little if any impact will be felt on the market or consumer level for many reasons: First, cigarette consumption per capita in 1977 for individuals 18 years and older was 4,064 pieces or 7.07 pounds of tobacco (203 packs of 20) (249). Therefore, each pack contains approximately .035 pounds of tobacco or 4.1 cents (based on the season average price for 1977 of 117.6 cents per pound). In August, 1977, the wholesale price of one pack of cigarettes was $0.22 (249). Adding in the Federal excise tax (8 cents) and the State cigarette taxes (13 cents; weighted by the number of packs taxed), the average value of a pack of cigarettes is $0.43 (249). Because 10 percent of the value of a pack of cigarettes is in the tobacco, only significant increases in the value of tobacco would

have an impact on the retail market and consumer levels.

No macroeconomic impacts are foreseen if EDB becomes unavailable.

LIMITATIONS AND ASSUMPTIONS

The analysis relies heavily upon persons with expertise in tobacco production rather than survey data on the quantity used, number of users, acres affected, or other appropriate measures. However, it represents the best available information on the subject. It is assumed that growers will not switch from a fumigant nematicide to a non-fumigant.

IV. ANALYSIS OF EDB USE ON PINEAPPLE

INTRODUCTION

EDB is used to control nematodes in Hawaiian pineapple fields. Hawaii produces 25 percent of the total world production of canned pineapple. The 1976 fresh pineapple production was 72,000 tons, which represents 50 percent of fresh pineapple consumed in the United States. The gross income reported from the production of pineapple in Hawaii in 1976 was $150 million. Hawaii's pineapple is grown on 43,000 acres, of which about 10,000 acres are planted each year (168).

Year-round employment is provided to 3,800 workers on plantations and in canneries, increasing to over 12,000 at the peak of the season. Wages paid to pineapple workers totaled $47 million during the past year (168).

Pest and Use Information

Nematodes represent a major parasite of pineapple. Without appropriate control measures, nematodes feeding on the roots can kill young pineapple plants or, at a minimum retard development so that marketable fruit is not produced.

Pineapples are a perennial crop. The production cycle ranges from three to five years, but generally lasts four. While there is some variation in cultural practice, the general procedure is to plant the pineapple (the appropriate nematicides are applied at this time) and harvest the first crop, referred to as the plant crop, approximately 18 months later. The second crop, the first ratoon, is harvested 12 months after the plant crop. The third harvest, the second ratoon, occurs 12 months later. The land is then allowed to lie fallow for approximately

six months prior to replanting.

All of the Hawaiian pineapple acreage must be treated with nematicides at planting to prevent damage by the root-knot nematode, Meloidogyne javanica (Treub) and/or the reniform nematode, Rotylenchulus reniformis (Linford).

Nematodes in the soil must be controlled by a reduction of the population prior to planting pineapple in the field. New roots become an excellent source of food for nematodes and if allowed to feed the population multiplies very rapidly. Feeding on the roots by these high populations reduces effective roots so that the plant either dies or is severely retarded. It is, therefore, important that the nematode population be reduced to a minimal level prior to planting. In moist soils where reniform and/or root-knot nematodes are present, it has been the practice for over 20 years to inject EDB into the soil at a rate of not more than 12 gallons per acre (16.6 lbs. a.i. per gallon) to a depth of at least 5 inches in the rows where pineapple are to be planted. DBCP is the preferred nematicide for dry soils. Application is made in conjunction with polyethylene film for soil sealing. After application, soil is left undisturbed except for planting. EDB is used on 2,875 acres annually (11,500 in a 4 year cycle) of moist soil to control the reniform and/or root-knot nematodes (169). Approximately 572,400 pounds a.i. of EDB are used annually for nematode control in pineapples.

The results of the application of EDB have been a 15-20 percent gain in yield in trials completed in the late 1940's and 1950's (25). In areas that have become infested with reniform nematodes, more recent trials show a 30-35 perent gain in yield resulting from application of EDB (25). In some fields without EDB fumigation, a complete crop failure has resulted (25).

In other areas of the world where pineapple is grown in moist locations, EDB has provided a 25-30 percent gain over non-fumigated areas (27).

Alternatives to EDB

Two additional fumigants have also been used in Hawaii: DBCP, and dichloropropene (either DD or Telone). Each of the three nematicides has specific characteristics that make one or the other (or a combination) the desired fumigant(s) depending on environmental characteristics, particularly soil moisture at the time of application.

(1) Dichloropropene (DD or Telone) is used on approximately 2,750 acres annually (11,000 acres over a 4-year cycle) of dry soil infested with root-knot nematodes only (169).

(2) A DBCP-dichloropropene combination is used on 5,125 acres annually (20,500 acres over a 4-year cycle) of dry soil infested with both the reniform and root-knot nematodes (168).

Dichloropropene is effective against root-knot nematode but not the reniform nematode. DBCP will kill reniform nematodes; however, due to its vapor pressure, DBCP is not suitable for use in moist soils. In these moist soils EDB is the desired fumigant. Yield gains from the use of EDB in comparison to DBCP have been 5 percent in the moist areas of Hawaii and 10-15 percent in wetter areas of the Philippines (where two of the Hawaiian pineapple companies also grow pineapple). DBCP performs better than EDB in dry soil applications.

Any change in the above nematode control practices (e.g., use of DBCP on moist soil) will result in increased nematode damage and reduced pineapple yields (26).

Recently, systemic nematicides have been tried experimentally. These are Nemacur and Vydate. In neither case have these nematicides proven to be a replacement of the foregoing more commonly used fumigants. However, in some instances they have provided improved production. This has been mainly due to repeat applications that have continued to suppress nematode populations (27).

ECONOMIC ANALYSIS

An EDB cancellation will result in changes in nematode control costs and yield losses due to increased nematode damage. The economic impact analysis is based on recent price (1978) and production data rather than historical averages. A review of the data has indicated that the Hawaiian pineapple industry has experienced a downward trend in total acreage and production and an upward trend in prices; therefore, this approach will more accurately reflect the current situation.

Since pineapples are a perennial crop with a 4-year production cycle, and one application of fumigants controls nematodes during the duration of the production cycle, the economic impact of an EDB cancellation will not be experienced on all pineapple acreage until approximately six years after withdrawal of EDB from the market. 1/

The average cost per EBD treatment is about $77.00 per acre ($6.40 per gallon of EDB) (27). If EDB is cancelled and a DBCP-DD treatment substituted,

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1/ This assumes that 1/4 of the pineapple acreage is planted each year and that yield losses occur in the 1st ratoon harvest.

nematode control costs will increase to $174.90 per acre, a $97.90 increase over EDB (27). In addition, yields are anticipated to decline, due to nematode damage, approximately 4.8 percent, reducing production from 80 tons per acre per production cycle to approximately 76 tons per acre per production cycle (169). At the current price of $110 per ton this loss of production is valued at $440 per acre. If EDB is cancelled, the additional nematode control costs and lost production will reduce net revenues approximately $538 (1978 dollars) per acre per 4-year production cycle (an average annual net revenue loss of $134.50 per acre).

The cancellation of EDB for use on pineapples would cost growers approximately $1.5 million (1978 dollars) per year until a satisfactory substitute for EDB is registered for use (Table IV-1).

The cancellation of EDB would reduce total Hawaiian pineapple production approximately 1.3 percent (a 4.8 percent yield loss on 26.7 percent of the Hawaiian pineapple acreage).

LIMITATIONS OF THE ANALYSIS

Because of the oligopolistic nature of the Hawaiian pineapple industry, specific information with respecct to price elasticity of demand is unavailable. However, due to increasing competition from foreign sources and the relatively small production decrease projected with an EDB cancellation (1.3 percent), it is expected that any price adjustment at the consumer level would be minor and the impact of an EDB cancellation borne by the industry.

Table IV - 1 User impact from EDB cancellation, 11,500 acres treated.

Year	Cost of control: EDB a/	Cost of control: DBCP-DD b/	Net increase in control cost	Value of production: EDB c/	Value of production: DBCP-DD c/	Net decrease in value of production	Decrease in net revenue	Present value of decrease in net revenue d/
	------	------	------	$1,000	------	------	------	------
1	221.4	502.8	281.4	25,300.0	25,300.0	0	281.4	281.4
2	221.4	502.8	281.4	25,300.0	25,300.0	0	281.4	263.0
3	221.4	502.8	281.4	25,300.0	24,035.0	1,265.0	1,546.4	1,350.7
4	221.4	502.8	281.4	25,300.0	24,035.0	1,265.0	1,546.4	1,262.3
5	221.4	502.8	281.4	25,300.0	24,300.0	1,265.0	1,546.4	1,179.9

a/ Based on an application rate of 12 gallons per acre at $6.40 per gallon on 2,875 acres per year.

b/ Based on an application cost of $174.90 per acre on 2,875 acres per year as supplied by Blomberg (27).

c/ Value of production with EDB based on price received of $110 per ton for average yield of 20 tons per acre annually on 11,500 acres treated with EDB.

d/ Discounted at 7 percent.

V. ANALYSIS OF ETHYLENE DIBROMIDE USE ON CITRUS GROVES

INTRODUCTION

Ethylene dibromide (EDB) is a fumigant nematicide registered for preplant use in fruit tree planting sites, including citrus groves. Target pests in citrus include the citrus nematode and the burrowing nematode.

The citrus industry is commercially important in Arizona, California, Florida and Texas. Average annual value of production for the U.S. was $1.2 billion for the 1975-1978 period (253). Florida produced citrus valued at $864.8 million or 72 percent of the value of the nationwide production. California produced citrus valued at $300.8 million or 25 percent of the value of nationwide production. The remaining production was distributed about equally between Arizona and Texas.

Pest Information

The citrus nematode infests groves in all of the citrus producing states - i.e., Arizona, California, Florida, and Texas. The citrus nematode infests about 53 percent of Florida citrus groves and is also widespread in California, where approximately 65 percent of the acreage are infested (216,105). From 80 to 90 percent of the Texas acreage and approximately 50 percent of the Arizona acreage are infested with this pest (120,105). A total of 680,000 domestic citrus acres (57 percent of U.S. total acres) are infested with and subject to damage by the citrus nematode.

The burrowing nematode is of greatest concern in Florida. This pest is the causal agent of spreading decline, a disease which is characterized by sparse foliage, retarded fruit growth, and a loss in fruit production

ranging from 40 to 80 percent. The burrowing nematode is introduced to citrus groves on the roots of young trees; once established, the nematode can spread within the grove at an average rate of 40 to 50 feet per year.

EDB Usage

EDB has two general use patterns in citrus. In the first instance, EDB is used on a broadcast basis to treat grove sites known to be infested with nematodes prior to the time the trees are set. EDB 84.5 percent is used at an average rate of 15 gallons (12 lbs. a.i. for 180 lbs. a.i.) per acre, applied by tractor-pulled injection chisels set on 12 inch spacing at a depth of about 10 inches. A float or roller device is pulled behind the chisels to seal the soil surface, thereby minimizing volatilization of the chemical. Review of public and confidential soil fumigant use data for citrus indicates no use of EDB in grapefruit or lemons and only a very small number of orange acres treated. No use of EDB in citrus has been reported in California during the past several years. Preplant broadcast use of EDB on citrus in 1977 was estimated at 20,000 pounds a.i.; this quantity would treat approximately 110 acres (296). About 14,000 acres of citrus have been set annually in recent years, indicating that less than 1 percent of the new citrus acreage receives preplant treatment with EDB (37, 70, 285). Postplant control of the citrus nematode is maintained by the use of DBCP every three or four years.

The second, and most important, use of EDB in citrus is the establishment and maintenance of a producer funded barrier program to contain the burrowing nematode in Florida. The area infested with the burrowing nematode centers on Winter Haven and ranges along a ridge from Ocoee to Sebring. EDB is chisel injected at a 12 inch depth (at a rate of 25 gallons per acre) on a broadcast basis in barrier zones or rows ranging from 16 to 32 feet in width.

Approximately 900,000 linear feet of row are maintained. Treatments are performed every six months; total annual EDB usage for this purpose is about 252,000 pounds a.i. This is enough to treat about 420 acres annually (25 gallons at 12 lbs. a.i. per gallon twice per year). Citrus in the region inside the barrier is pushed out when no longer profitable and the land is either fumigated and replanted with citrus or put to an alternative use.

EDB is not among the materials included in state pesticide recommendation guides for nematode control in citrus, but it is used in the cooperative State-grower program in Florida to control dispersion of the burrowing nematode. The nematicides recommended for preplant control in citrus include: dichloropropene (Telone), dichloropropene - dichloropropane (D-D) (California and Florida); DBCP (Florida and Texas); chloropicrin, methyl bromide, Vapam (metam-sodium), Vorlex (methyl isothiocyanate (20 percent) plus chlorinated c_3 hydro carbons 80 percent) (California) and Dasanit (fensulfothion), as a bare root dip for seedlings (Florida). Both nematode types attack citrus tree roots, causing reduced growth rates, tree debilitation, lower fruit yield, and reduced fruit quality. Debilitated trees are not killed outright but slowly decline in productivity so that in time they become marginally productive and are eventually pushed out.

Alternatives to EDB

D-D and Telone are the most viable alternatives to EDB in both citrus use patterns. DBCP is another potential though less desirable alternative to EDB for both uses. D-D and Telone provide similar control to EDB in controlling the citrus nematode and are the nematicides commonly used for preplant nematode control.

DBCP will not kill all citrus roots which is necessary to effectively control the burrowing nematode. Therefore, DBCP is not considered a viable alternative. D-D and Telone are less effective than EDB in the burrowing nematode control program.

ECONOMIC IMPACT ANALYSIS

Citrus growers currently utilizing EDB for preplant control of citrus nematodes are not likely to experience significant changes in levels of control following adoption of D-D or Telone. However, the use of these materials will increase treatment costs considerably. The per acre cost of control with EDB approximates $82.50 ($5.50/gallon of EDB (84.5 percent) x 15 gallons/acre) compared to $100.00 with D-D ($2.50/gallon x 40 gallons/acre) and $128.00 with Telone ($4.00/gallon, at 32 gallons/acre). The use of D-D or Telone will increase per acre treatment costs by $17.50 (21 percent) and $45.50 (55 percent), respectively. The use of D-D and Telone in place of the 20,000 pounds EDB active ingredient applied to 110 citrus acres in 1977 will increase grower treatment costs by a total of about $3,500 annually ($31.50/ acre average cost increase for 110 acres). The methods of treatment remain unchanged, but application costs will rise due to the increase in transportation and handling costs because of the greater quantities required for treatment if D-D (40 gallons/acre) and Telone (32 gallons/acre) are substituted for EDB (15 gallons/acre). Lack of information prevents quantification of the costs of these logistical items at this time.

The USDA-State barrier control program for burrowing nematode containment will probably also utilize D-D and/or Telone in the event EDB is unavailable. It is likely that this program, in which EDB is utilized at a rate equivalent to 25 gallons per acre, would also require greater than normal quantities of D-D and Telone on an area basis. Assuming that the percentage

increase in gallons of EDB applied for this use relative to the normal preplant application rate (167 percent; 25 gallons/acre versus 15 gallons/acre) can be applied to determine the required gallons for D-D and Telone, 67 gallons of D-D or 53 gallons of Telone would be required per acre. The per acre costs of treatment with EDB, D-D and Telone at the increased rate would be $137.50, $167.50, and $212.00, respectively. The area treated with EDB twice annually represents the equivalent of approximately 840 acre-treatments. Thus, the use of D-D and Telone in this capacity would increase the program costs from $25,000 to $63,000 per year, depending upon whether D-D or Telone were used in place of EDB.

As in the case of the preplant use of EDB, the adoption of D-D or Telone in the burrowing nematode control program would increase transportation and handling costs due to the increased volume of required materials. However, the costs associated with this aspect have not been quantified.

As previously indicated, the use of D-D or Telone in place of EDB will not create impacts other than control cost increases. Since EDB use for citrus nematode control is very limited and since no change in quality or yield effects are associated with the use of D-D or Telone, the cost effects resulting from the loss of EDB for preplant citrus use will be absorbed at the grower level, with no market or consumer impacts anticipated.

The loss of EDB for use in the burrowing nematode control program has economic implications beyond the relatively small cost increases associated with the use of D-D or Telone. Control is reported to be better with EDB in the soil types and temperatures encountered in the program area. Reduced control levels could lead to a further increase in the range of the burrowing nematode in Florida citrus groves, resulting

in the problems associated with spreading decline. Barring the introduction of an effective nematicide or another control agent, expansion of this disease over a period of years could lead to significant declines in citrus yield and quality. Growers affected by this problem could be expected to abandon declining groves and establish new groves in non-infested areas or get out of the business. In the longer term, if unsolved, the burrowing nematode-spreading decline effect could reduce citrus supplies to the point at which consumers would begin to be affected by higher retail prices and/or reduced quality of citrus and citrus products. However, this situation would be alleviated somewhat by plantings in non-infested production areas and/or introduction of new control materials or techniques.

LIMITATIONS OF THE ANALYSIS

This analysis is limited by data gaps in several areas. First, EDB usage data for preplant nematode control in citrus are almost nonexistent. Secondly, no yield or quality effect data are available to estimate the changes (if any) likely to occur if alternative materials are used in place of EDB in both the preplant and burrowing nematode use patterns. Third, little is known regarding the overall impact upon domestic citrus production likely to occur in the event alternative materials to EDB are not effective in containing the spreading decline problem.

VI. ANALYSIS OF EDB USE ON PEACHES

INTRODUCTION

Peach production in the U.S. is centered primarily in California and the Southeast. Table VI-1 presents production by state for recent years. California is by far the largest producer and uses no EDB in peaches. (38, 48, 105).

Table VI-2 presents historical data on per capita consumption of peaches.

Pest Information

Major Nematode Pests: Ring (*Macroposthonia xenoplax*), root-knot (*Meloidogyne* spp.), lesion (Pratylenchus spp.) and dagger (*Xiphinema* spp.) are demonstrated pathogens of peach trees. The ring and root-knot nematodes in the Southeast and West, (124, 290) and the lesion nematode in the Northeast, Southeast, and West, have been implicated with trees in a declining state of vigor (290). Ring nematode infested trees have been shown to have increased susceptibility to bacterial canker (*Pseudomonas syringae*) in California (124), and increased propensity to bacterial canker and cold injury in the Southeast (147). In the Southeast other management factors such as the time of pruning, discing practices, selection of root stocks, fertility, use of herbicides, pH, site selection, and removal of dead trees and limbs influence tree life (31). Proper management of the above factors without appropriate nematode control results in premature death of trees and loss of productive limbs in regions having nematode problems (31). The average life expectancy of peach trees in nematode infested soils in the Southeast is 6-7 years (31). The life expectancy of trees receiving pre- and post-plant nematicides

Table VI-1

Peach Production and Prices

State	1978 Estimated production (Million lbs)	1977 Total production (Million lbs)	Price per pound (¢)
NC	44.0	35.0	12.4
SC	230.0	275.0	14.2
GA	145.0	90.0	15.3
TX	45.0	48.0	14.0
CA Freestone	430.0	476.0	7.0
Clingstone	1,150.8	1,508.0	8.8
NJ	80.0	110.0	17.0
PA	85.0	95.0	12.9
MI	55.0	55.0	15.6
VA	40.0	15.0	12.0
WA	41.0	41.0	10.9
U.S. TOTAL	2,631.4	2,991.0	9.9

Source: USDA Crop Reporting Board. 1978 Non-citrus Fruits & Nuts 1977 Annual Summary.

Table VI-2

Annual Per Capita Consumption of Peaches

Year	Pounds consumed				
	Dried	Frozen	Canned	Fresh	Total
1970	.01	.26	5.9	5.7	11.87
1971	.02	.25	5.4	4.7	10.37
1972	.02	.31	5.7	3.9	9.93
1973	.01	.22	4.9	4.3	9.43
1974	.01	.28	5.0	4.4	9.69
1975	.02	.28	4.9	5.1	10.30
1976	.02	.13	5.0	5.3	10.45
1977	.01	.28	5.1	5.4	10.79

Source: USDA. Fruit Situation. July 1978.

is estimated to be 12-13 years provided good management practices are followed. Some individual orchards that have received adequate nematode control and proper management are living 15-20 years. In California the expected life of untreated peach trees is 10 years compared to 20 years with nematode control.

EDB is an effective preplant fumigant for protecting peach trees from loss caused by nematode damage for from two to four years (51), and increasing yields twofold over non-treated trees at least for the first two years (74).

Extent of Use and Application

Preplant fumigants are applied in bands which cover from 1/3 to 1/2 of the actual surface areas of an acre (267). An actual application rate of 85 pounds a.i. per acre was used to calculate total pounds a.i. (86). The label rate calls for a broadcast rate of 180 lbs. a.i. per acre. Thus, the actual rate is 47 percent of the label rate because of the band application technique. A total of 170,000 pounds a.i. of EDB is estimated to have been applied in 1976 (Table VI-3).

Alternatives

EDB is used only as a preplant control of nematodes. DBCP is the only fumigant which can be used as a postplant treatment for peaches. In this analysis only preplant applications of fumigants will be discussed. Preplant fumigants are applied using injection chisel equipment.

EDB treatments are applied to approximately 10 percent of all peach

acres planted annually (Table VI-3). EDB usage is centered primarily in the peach growing regions of the eastern United States. Approximately 44 percent of the acres planted annually are treated with DBCP. The remainder of the acres planted are either treated with one of the remaining alternatives or not treated at all. Data on usage of the remaining alternatives were not available.

Each of the four major preplant fumigants (EDB, DBCP, D-D, Telone) gives results comparable to the other three. For the purpose of this analysis, it will be assumed that each fumigant is identical to all others in terms of level of control and yield or quality of the commodity.

The comparative costs of each of the four major fumigants ranges from a low of $51.45 for EDB to a high of $110.54 per acre for Telone (Table VI-4).

ECONOMIC ANALYSIS

User Impacts

The impacts on growers from a loss of EDB would take the form of a change in cost for preplant fumigants. There will be no yield or quality of product changes with substitutes. If producers were to substitute DBCP for EDB, the growers would realize a cost increase of $20,300 (Table VI-5). If Telone were substituted, the impact would be $118,180. If 1/3 of the 2,000 acres treated with EDB were treated with each of the alternatives, the impact would be $70,613.

Table VI-3

Preplant Use of EDB and DBCP in Peach Orchards - 1976

Region	Acres planted[a/] annually	Acres preplant treated with DBCP annually	Percent DBCP treated f/	Acres treated[b/] with EDB	Percent EDB treated	Pounds a.i. of EDB[c/]
East	13,445[d/]	6,225[d/]	46.3	NA	NA	NA
California	4,121	2,000	48.5	0	0	0
Other	1,545[e/]	100[e/]	6.5	NA	NA	NA
Total	19,111	8,325	43.6	2,000[b/]	10.5	170,000

a/ From USDA-EPA. 1978. Economic and Social Impacts of Cancelling Use of DBCP as a Pesticide for All Registered Use Sites with Known Current Usage. Washington, D. C. March. p. 1-5.

b/ From discussions with the below listed references and a review of the below listed report. They were unable to estimate where the EDB was used.

(1) Johnson, D. E. Extension Plant Nematologist. 1978. Personal Communication. Parlier, CA. 14 September.

(2) Springer, J. K. 1978. Personal Communication. Rutger Research and Development Center. Bridgeton, N.J. 13 September.

(3) Great Lakes Chemical Company. 1978. Benefits of Ethylene Dibromide to Agriculture. West Lafayette, Indiana.

c/ assumes an actual application rate of 85 pounds per acre. Preplant fumigants are applied in bands covering from 1/3 to 1/2 of the surface area of an acre.

d/ includes the following states: CT, DE, FL, GA, KY, MD, MA, MS, NC, NJ, PA, SC, VT.

e/ includes the following states: AR, CO, ID, IL, IN, LA, OH, OK, OR, WA.

f/ percents are percent of each region total plantings and percent of total plantings.

Table VI-4

Comparative Costs of EDB and Alternatives

Chemical	Cost/gal[a] ($)	Actual application[b] rate per acre	Chemical cost per acre ($)
EDB	7.35	7.0 gal	51.45
DBCP	22.00	2.8 gal	61.60
D-D	3.75	23.5 gal	88.13
Telone	5.88	18.8 gal	110.54

a/ 1978 estimated prices.
b/ derived from North Carolina state recommendations.

Table VI-5

Cost Increases Using Several Alternatives
To EDB as a Preplant Fumigant for Peaches

Region	Per acre cost impact using alternative chemicals ($) a/			Total cost impact using alternative chemicals ($)		
	D-D	Telone	DBCP	D-D	Telone	DBCP
East	36.68	59.09	10.15			
California	—	—	—	0	0	0
Other	36.68	59.09	10.15			
Total				73,360	118,180	20,300

a/ From Table VI - 4.

b/ 2,000 acres are treated annually with EDB (see Table VI-3).

LIMITATIONS OF THE ANALYSIS

The majority of the data used was initially obtained through personal communications with knowledgeable experts in peach growing states. Sufficient data were not available to estimate regional breakdowns of EDB treated acreage; only U.S. total was available.

VII. ANALYSIS OF EDB USE IN FORESTRY

INTRODUCTION

Ethylene dibromide (EDB) is registered for control of several western bark beetle species infesting coniferous trees. Of the products available, only one was found currently used, a registration held by USDA and restricted to certified applicators on Federal-State cooperative projects.

Coniferous trees are important for many reasons, ranging from their use as the basic raw material for the United States forest products industry to providing amenity values in suburban residential areas. They are subject to attack by pests, including some kinds of insects that can be controlled in part by using EDB.

In general the land on which beetle control is practiced in the Rocky Mountain area is managed for purposes other than timber production; e.g. mountain home developments, recreation, watershed protection, wildlife habitat, or a combination thereof. The land is mostly privately owned.

Pest Information

The EDB labels for forestry use include "Black Hills beetle, Jeffrey pine beetle, and mountain pine beetle" all lumped under *Dendroctonus ponderosae* (Hopkins). Black Hills beetle is an old common name for mountain pine beetle. Jeffrey pine beetle is now regarded as a separate species, *D. jeffreyi* (Hopkins). Other species named include California flatheaded borer, *Melanophila californica* (Van Dyke), roundheaded pine beetle, now *D. adjunctus* (Blandford), Douglas-fir beetle *D. pseudotsugae* (Hopkins), and spruce beetle, given on some labels as *D. obesus* (Mannerheim); now known as *D. rufipennis* (Kirby).

Adult beetles damage trees by boring through the bark to the cambium

layer, then tunneling upward to interfere with sap flow. Larvae feed on the inner bark and nutrient translocation system, causing tree decline and eventual death (135). Each infested tree not treated can be expected to infest an additional 1.5 to 2 trees per year (209).

EDB Usage

Table VII-1 gives the reported use of chemicals for control of mountain pine beetle, the only forest pest for which EDB is reported used. Control levels vary from year to year in part because insect populations fluctuate. Less than 1 percent of the forestry use of EDB in FY 1977 was on National Forest System Lands. EDB was used in State-Federal cooperative projects for private forest land in Colorado (97 percent) and South Dakota (2 percent) (256).

Under terms of cooperative projects in Colorado, private forest landowners commonly cut infested trees and limbs and buck them in preparation for spraying. A Colorado State Forest Service (CSFS) team, a forester as the certified applicator plus a crew of summer help, conducts the treatment operation.

EDB is applied in one of two ways. In "open log" spraying, the entire bark surface of each log is sprayed. In "under plastic" spraying, reduced amounts are applied to cordwood stacks, which are then covered airtight with 6 mil thick, clear plastic. CSFS estimates that 88 percent of the trees sprayed with EDB in 1977 were treated using the "under plastic" method (119).

In Colorado, the EDB product is mixed with water in a 1:4 ratio. In "open log" spraying, an average of four gallons of this final spray is applied to each tree (1.6 lbs. a.i. per tree). In "under plastic" spraying, two gallons will treat one cord, or seven trees (0.11 lbs. a.i. per tree).

Table VII-1

Reported Use of Chemicals for Control of Mountain Pine Beetle-Fiscal Years 1975-1977 (in pounds active ingredient)

	Fiscal Year 75	Fiscal Year 76 a/	Fiscal Year 77
EDB	26,326.0	17,534.0	19,695.0
Lindane b/	3,065.0	616.0	334.6

a/ Fifteen-month fiscal year.

b/ Includes use to control several other forest insects.

Source: USDA, Forest Service, (256, 257, 258).

Registered Alternatives

Lindane, currently under RPAR review, is as efficacious as EDB and can be applied by the private owner. The decision to cancel or continue its registration, however, is still pending, and its continued availability is uncertain.

Endosulfan is also registered but has not been reported used for bark beetle control in the Western States. The effectiveness of endosulfan is uncertain. While no studies were located which compared it with EDB for control of mountain pine beetle, studies using endosulfan and lindane on other Dendroctonus species seem to indicate that endosulfan will not be as effective (187). Probably more of it would have to be used, with more frequent treatment.

Non-chemical Control Alternatives

Prevention: Certain forest management practices (silviculture) can be used to promote vigorous, healthy tree growth which minimizes bark beetle attacks. Such practices include choosing favorable sites, promoting stands of several species instead of monoculture, thinning to decrease competition, and removing injured or diseased trees promptly. Unless a forest landowner is managing the stand for timber production, most preventive practices are not economically feasible. They cost more than the value they add to the stand over its life.

Suppression: Non-chemical methods such as; salvage logging, cut-and-burn, and peeling bark from logs can be used to reduce existing populations.

In severe epidemics, such as the existing one in Colorado and in South Dakota, these methods are not effective by themselves. Further, logging is generally precluded on steep slopes, and burning may be undersirable, or restricted by air quality standards around Denver.

Again, these methods are impractical or inappropriate for the small forest landowner, especially those concerned more with wildlife habitat, aesthetics, watershed protection, and recreation than with timber production. Because most of the infested areas fall in this category, the non-chemical control methods are not considered satisfactory alternatives to EDB in this analysis.

ECONOMIC IMPACT ANALYSIS

The direction and magnitude of any economic impact of an EDB cancellation for forest use will depend on whether the alternative chemicals are available and equally efficacious.

User Costs

Using the total pounds of EDB reported and the application rate referred to above, an estimated 68,196 trees 1/ could have been treated in 1977.

Cost impacts, if EDB were not available for forest use, would depend on the chemical alternatives available. Assuming lindane registration

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1/ Let X = total number of trees treated in 1977.
Then .11 (.88X) + 1.6 (.12X) = 19,695
.2888X = 19,695
X = 68,196 trees
Then 88% X = 60,012 trees treated using under plastic
12% X = 8,184 trees treated using open log.

Table VII-2

Comparative Cost of Chemical Alternatives for Control of Mountain Pine Beetle, 1978

Chemical	Method	Cost of chemical ($ per gal.)	Carrier	Cost of carrier ($/gal.)	Ratio of chemical to carrier	Quantity of final spray per tree	Chemical cost per tree	Added labor cost	Added material cost[a]	Total cost per tree	Number of trees treated[b]	Total annual cost of control
EDB	open log	2.73	water	-	1:4	4 gal.	$2.18	-	-	$2.18	8,184	$17,841
EDB	under plastic	2.73	water	-	1:4	2/7 gal.	$ .16	$.32[c]	$.30	$ .78	60,012	$46,809 $64,650
Lindane	-	14.87	diesel	.45	1:15[d]	1 qt. 2 qt.	$ .34 $ .68	$.50[e] $.50	-	$ .84 $1.18	68,196 68,196	$57,285 $80,471
Endosulfan	-	5.30	water	-	2:98	4 gal.	$ .42	-	-	$ .42	68,196	$28,642

a/ Plastic wrap, $17.00 per roll, average of 8 cords per roll, 7 trees per cord.
b/ Based on pounds reported used in 1977 and estimated rate of application.
c/ Labor needed to cover the stacked wood after spraying, .75 hour per cord at $3.00 per hour.
d/ McWhorter, 1978.
e/ Labor needed to turn each piece of wood so that all sides are treated.

Source: Derived from Leatherman, 1978.

for forest use is continued, the impact could range from -$7,365 to $15,821 depending on application rate (Table VII-2). At a rate of 1.5 gallons of spray per tree, the impact would be $4,228 (assuming the same number of trees treated). This is the preferred alternative, since little efficacy data can be found for endosulfan.

If lindane registration for forest use is also cancelled, impacts using endosulfan appear to be a saving of $36,008 (Table VII-2). This is probably overstated, since if it is less efficacious, either more trees will have to be treated due to less effective control of insect populations or trees will have to be treated more than once in a season. Both would increase control costs, but the extent of the increased costs cannot be determined.

Other Costs

Other losses with endosulfan can be expected. In Colorado, where most EDB is used, most forest land is managed for non-timber purposes, e.g., recreation, wildlife habitat, aesthetics (255). Owners may have neither the interest nor the finances to use management practices designed to prevent large beetle infestations. Suppression techniques without effective chemicals are difficult because of terrain, state regulations, and/or owner preferences. The impact of unavailability of effective chemical control, therefore, would be reflected more in changes in property values than in control costs. Healthy trees add to the enjoyment of most mountain uses. The Colorado State Forest Service estimated that trees contribute about 15 to 25 percent of residential lot value. With some residential lots in the impact area valued at $10,000 to $12,500 (255), this loss of

value could range from $1,500 to $3,125 per lot. In addition, construction of new facilities and recreational homes in the impact area would decline, possibly aggravating local unemployment problems.

LIMITATIONS OF THE ANALYSIS

Limitations of this analysis include lack of data on number of trees actually treated, efficacy of endosulfan for control of this pest, and uncertainty of future availability of lindane, future levels of insect infestation, and values of non-monetary impacts.

VIII. ANALYSIS OF EDB USE FOR SUBTERRANEAN AND DRYWOOD TERMITE CONTROL

INTRODUCTION

Ethylene dibromide (EDB) is the only registered fumigant for subterranean termite control and is registered for drywood termite control only in California (273). Subterranean termites are found throughout the United States. They are a serious problem to wood structures in the Southern States, especially in areas with warm, humid climates. Drywood termites are a serious problem in warm, humid areas of California, Georgia, North Carolina and South Carolina.

EDB Usage

EDB is used to control termites under concrete slabs and in heavily infested inaccessible places when other control measures have failed. Two formulations are used. STD is a mixture of 15 percent EDB, 5 percent chlordane, and aliphatic thinners. STD is used beneath concrete slabs. A hole is drilled through the slab, the fumigant is applied, and the hole is plugged. Rate of appliction is 3 pints per hole at 5 foot spacing or 2.5 pints per hole at 2.5 foot spacing. The other formulation, KTD is a mixture of 5 percent EDB, 1 percent lindane, and aliphatic thinner. This is used on above ground infestations of drywood termites (*Kalotermes* sp.). Three to ten cubic centimeters of the material are injected with a hypodermic syringe into the channels of each colony. Estimates of total use vary from 5,000 to 12,000 gallons of formulated product per year (171).

EDB is not included in recommendations of 20 States (AL, AR, CA, FL, IN, KY, MI, MO, MT, NC, NM, NY, OH, OK, PA, SC, SD, TN, TX, VA) for subterranean

termite control. The same 20 states recommend chlordane, and 11 states (AL, AR, IN, KY, MT, NC, NY, OK, TN, TX, SC) recommend aldrin and dieldrin for subterranean termite control. Eleven states (AL, AR, IN, KY, MO, MT, NC, OH, OK, SC, TX) also recommended heptachlor. Very few states (California, Florida, North Carolina, and South Carolina) provide recommendations for drywood termite control. EDB is registered for drywood termite control only in California. However, California recommends only silica aerogel and Florida, pentachlorophenol.

Alternatives to EDB

Registered liquid insecticides for subterranean termite control considered effective are aldrin, chlordane, dieldrin, and heptachlor. Drywood termite control may be achieved using methyl bromide, sulfuryl fluoride, silica aerogel, pentachlorophenol (under RPAR review) and hydrogen cyanide.

EDB is used as a last resort treatment to control subterranean termites. Therefore, for this purpose there is no alternative to EDB for subterranean termite control.

EDB is used only to control new, limited and visible drywood termite infestations. Under these conditions, only the infestation is treated. The alternative procedure would be to treat the entire house.

The application rate for one formulation (EDB and chlordane; applied under concrete slabs) is three pints per hole spaced at five foot intervals adjacent to either wall or pier foundations, under cold joint failure, or where cracks permit entry of insects. Ehman (1978) indicates that "...where

conventional methods have failed. (One) could treat five to possibly fifty lineal feet in one structure."

The treatment of 5 lineal feet in a structure would be a spot treatment consisting of one hole. Treatment of 50 lineal feet would require 10 holes and treatment would be confined to those areas infested or potential sources of termite entry into the structure. Therefore, .38 to 3.75 gallons (0.87 lbs a.i. to 8.63 lbs a.i.; 3 pints = about .38 gallons and 30 pints at 3 pints per hole would equal 3.75 gallons) may be used per structure. The wide range in estimated use of EDB per structure (.87 to 8.63 lb. a.i.) and total estimated use of EDB for termite control 11,500 to 27,600 lbs. a.i.) leads to a wide range in possible number of structures treated annually (1,333 to 31,724). The simple average of the range (16,528) provides a point estimate of the number of structures treated in 1977. No data are available indicating units treated for drywood termite control.

ECONOMIC ANALYSIS

Subterranean Termite

EDB, applied by pest control operators only, should be considered a last resort treatment for subterranean termite control under concrete slabs (127, 174). The chemical and application costs are highly dependent upon many variables, but in Atlanta, Georgia, the EDB chemical cost per 1,000 square feet is estimated to be $11.00 (127) 1/ Ehman (1978) indicates that:

"operators usually figure fifty cents per hole for drilling through the concrete and then add a labor change for application depending

1/ If EDB becomes unavailable, the chemical and application cost of using other liquid chemicals is dependent upon the number of additional holes needed to be drilled to locate the colony.

upon the unit charge per man for each applicator in the company. This could be as much as $40.00 per hour. If there were ten holes to be treated in one hour.....both the number of holes and unit cost per laborer varies from company to company and from one geographical area to another."

Drywood Termite

Houses with new, limited, and visible drywood termite infestations may be treated with EDB in California only. Injected by hand, under the above conditions, costs may range between $50 and $75. The insecticide cost per 1,000 cubic feet for sulfuryl fluoride and methyl bromide is $4.30 and $2.59, respectively (59). The chemical and treatment cost for a 30,000 cubic foot house may range between $400 and $500 (94).

Given the current data limitations, the magnitude of these impacts cannot be accurately quantified nor can the distribution of impacts be determined. Experts in the field indicate that:

> "The whole point is not the volume that is being used because that is infinitesimal. The real point is that this is an important tool in the controlling of stubborn termite infestations and should be safeguarded in the interest of the public who are homeowners and who are interested in protecting the equity in their homes" (63).

IX. ANALYSIS OF EDB USE IN GRAIN BIN FUMIGATION

INTRODUCTION

EDB is registered for use on stored grains alone or in combination with carbon tetrachloride and ethylene dichloride. It is used in on-farm and off-farm storage facilities. Little information exists on the number of on farm storage facilities or the quantity of grain stored in them. There were approximately 15,000 off farm grain storage facilities with a capacity of 6.6 billion bushels in 1978.

Pest Information

Stored grain will become infested with insects unless measures are taken to protect it. The insects feed on and damage the grain, ultimately destroying it completely if not controlled. The hazard of infestation and damage is greater in the South where the warm season is longer and more generations of insects can develop. Some grains produced in the southern part of the nation become infested in the field before harvest. They cannot be stored unless they are fumigated when placed in storage.

A large number of different kinds of insects attack stored grains. Most of them are widely distributed throughout the country. The more common kinds include the rice and granary weevils, Angoumois grain moth, lesser grain borer, flat grain beetles, saw-toothed grain beetle, red and confused flour beetles, several species of *Trogoderma* dermestid beetles, Indian-meal moth, grain mites, cadelle-mealworms, spider beetles, foreign grain beetle, and hairy fungus beetle.

Registration

EDB is registered as a component of grain fumigants in amounts ranging from 2 to 30 percent. Uses include treatment of grain storage facilities, farm buildings, and rail cars. The grains treated include barley, corn, oats, rice, rye, sorghum, and wheat.

Application and Human Exposure

Gas masks are required during the application of grain fumigants and in preparation for or during aeration of the bins after fumigation, thereby minimizing human exposure.

Extent of Use

There is very limited information available as to the amount of EDB used in grain fumigants. Estimates range from 675,000 pounds to less than 100,000 pounds annually. There has apparently been a decline in use during the last 20 years. Industry is in the process of trying to develop some more reliable information.

Environmental Impact

Grain fumigants are applied inside the constraints of the storage bins, which are usually concrete or metal. They must be relatively air tight in order to hold the fumigant gas and produce the required insect kill. The application should not comprise a hazard to birds, pets, wildlife, or aquatic organisms.

Alternatives

As long as carbon tetrachloride remains available, liquid fumigants without EDB in the formulation can be used. They already represent the major quantity of grain fumigants used.

Carbon tetrachloride is a major component of almost all liquid grain fumigants, and is on the RPAR list. Loss of the use of liquid grain fumigants would cause problems. They are particularly useful for treating farm-stored grain, and increasing quantities of grain are being stored on the farm.

Grain fumigants other than the liquid fumigants are methyl bromide and aluminum phosphide. There is a question whether there would be enough of these compounds available to supply all the needs for grain fumigation. There are also limitations on the way these fumigants can be applied and they would not meet the requirements for grain fumigation under some circumstances.

Methyl bromide is not as toxic to most stored product insects as EDB. Aluminum phosphide and methyl bromide must be used in a tight container and some farm and small elevator storage facilities might not provide tight enough structures for effective fumigation.

A grain protectant such as malathion can be applied to uninfested grain as it goes into storage to prevent insects from becoming established during storage. Its effectiveness lasts for about one year. Some insects have developed resistance to malathion and the treatment is not used as extensively as it was a few years ago. A grain protectant can be helpful in reducing the need for fumigation, but it is not an alternative to fumigation for killing out an infestation that already exists in the grain.

Non-Chemical Control

Part of the rules for proper grain storage relate to protecting the grain from weather, and keeping it as cool and dry as possible. This helps to reduce the insect problem but is seldom totally effective so that insecticidal treatment is not needed.

ECONOMIC ANALYSIS

Information regarding the benefits of EDB use on stored grains can be obtained from the report prepared for EPA by Development Planning and Research Associates, Inc. (307).

This report concludes the cancellation of EDB as a grain storage fumigant would result in cost decreases of $2.7 million. However, aluminum phosphide as an alternative treatment requires certified applicators which often would create an additional cost to users.

X. ANALYSIS OF EDB USE IN FLOUR MILLS

INTRODUCTION

EDB is registered for use as a spot fumigant in flour milling machinery. There are about 391 commercial flour mills in the U.S. having a daily milling capacity of approximately 1.3 million hundredweight. There are also small specialty flour mills which are not included in these estimates.

Pest Information

Inside milling machinery and handling systems for flour, meal, and other milling streams there are ledges and other obstructions that cause dead spots where the product accumulates. This stationary product readily becomes infested with insects. As the insects multiply the excess population gradually overflows into the milling stream as it passes, thus contaminating the entire production. The periodic application of a "spot fumigant" into critical spots in the machinery, ducts, and conveyors sterilizes the accumulated product. Proper timing of the applications break the life cycle of the insects and prevents the tremendous population increase that would result from the development of succeeding generations.

All of the common kinds of insects that infest cereal products are likely to be pests in milling machinery and equipment. This includes red and confused flour beetles, saw-tooth grain beetle, flat grain beetle, foreign grain beetle, Mediterranean flour moth, cigarette beetle, lesser grain borer, cadelle, black carpet beetle and other dermestids, grain mites, and Indian-meal moth. The species may vary depending on the part of the country and the type of milling facility or the commodity being processed or handled.

Registration

The primary registered uses for EDB as a spot fumigant are in cereal processing equipment, flour elevators, empty flour bins, flour mill equipment, grain mill equipment, and grain mill machinery.

Application and Human Exposure

Spot fumigants are applied over a weekend when the mill is closed down, perhaps for other sanitation operations, or for repairs or maintenance. After other personnel have left the premises the fumigation crew, wearing gas masks, treat the spots needing attention. Some milling systems have been equipped with built-in fittings for attaching the fumigant gas dispenser, thus avoiding introducing any gas directly into the ambient atmosphere in the building. After the fumigant has been introduced all personnel leave the building and lock it. The next morning the fumigation crew opens the building and aerates it before operating personnel report for duty.

The procedures for conducting spot fumigations in mills have been developed with the objective of eliminating human hazards and of insuring a safe procedure as well as an effective one. It has been a number of years since gas concentration studies have been conducted in relation to operator exposure during spot fumigation in mills. The older air sampling methods and chemical analytical procedures are now suspect in the light of recent technological advances. Therefore, new studies have been conducted by industry to obtain updated information. Residue studies in the milling products after spot fumigation have also been conducted. The new data will be submitted as a supplement to this report.

Extent of Use

EDB is formulated with other fumigants for use as a spot fumigant. The EDB content is usually 59 percent or 75 percent. The actual amount of EDB used annually in these formulations, according to four different estimates, ranges between 382,000 and 400,000 pounds.

Environmental Impact

The spot fumigation of milling machinery is an indoor, non-domestic use of an insecticide. There is no likely probability of contact with the gas by birds, pets, wildlife, or aquatic organisms.

Alternatives

The only alternative spot fumigant that does not contain EDB is a mixture of 75 percent ethylene dichloride and 25 percent carbon tetrachloride by volume (70:30 by weight). This mixture is considered by the milling industry to be so poor in performance that it can hardly be classed as a viable alternative. It must be used more frequently to exert any reasonable degree of control. The rate of application may be two to four times that of the EDB fumigants. The large amount of liquid material applied may cause the system to clog up, and this requires extra preparation time before milling can be resumed. The total results of using the alternative include the actual application of a much greater quantity of chemicals and a greater cost for fumigant, the use of more labor, more down time of the mill and the loss of revenue, and an overall much less favorable cost-benefit ratio.

Carbon tetrachloride, an ingredient in the alternative spot fumigant, is also an RPAR candiate. If that compound should also be lost for use, then no spot fumigant remains. If carbon tetrachloride should be lost, but EDB retained, this would leave one formulation of EDB and methyl bromide still available for spot fumigation.

The only alternative to spot fumigation itself is a general fumigation of the entire mill. This requires the mill to be closed down for several days, and is a very expensive operation. Furthermore, it uses an excessive, wasteful, and unnecessary amount of chemical because the entire mill structure has to be filled with gas in order to reach the limited number of spaces that would be treated in a spot fumigation. Opinions vary as to how frequently general fumigation would be required in the absence of spot fumigation. Some believe every six months might be enough but others estimate it would be needed every three months.

Non-Chemical Control

There are some measures that are taken as supplements to chemical control, as part of a pest management system. The milling and other food industries have long recognized the importance of good housekeeping and thorough cleaning as the backbone of pest prevention and control. Sweeping and vacuum cleaning are routine procedures in a flour mill. New mills are built so there is a minimum of cracks, crevices, and voids where product dust can accumulate and where insects can hide and multiply. In older mills there is usually a continuing program of renovation, closing up, and elimination of places where insects can develop. For a number of years there have been attempts to redesign milling machinery and equipment so as to eliminate dead spots for product

accumulation. Progress has been made, but it is a slow and expensive procedure. Mills are also taking steps to seal and close various structures to prevent the entry of insects and other pests. This has gone to the extent in some cases of closing off and filling in all windows. Another measure is to be watchful of the quality of raw grain used for milling, to minimize the possibility of bringing live insects into the mill.

Returning consideration to the point of the dead spots, one might ask why not clean them out rather than apply a fumigant. This too is done as much as possible by brushing and vacuuming. But it is not possible to gain access to all of the locations because of the nature of construction of some of the machinery, equipment, and duct systems. Physical configuration of even the accessible locations may make it difficult or impossible to achieve complete cleaning.

Attention to all the above measures is useful in helping to prevent insect infestations in flour mills. The various species of pest insects are so abundant and widespread, and the pressures of infestation hazards are so great that the measures described are not effective by themselves in preventing the insects from becoming established in the mills. The supplemental use of fumigants and other insecticides is required to round out the pest management system. Without the use of effective insect control measures an entire production run of wheat flour, corn meal, cake mixes, breakfast cereals, and similar products could be so heavily infested they would not meet the requirements of customers or the Food and Drug Administration. The real trade-off here may be between the cost of spot fumigation and general fumigation. An assumption has to be made on the required frequency of general fumigation needed. This will vary according to such factors as geographic location, type of product being milled or produced, and nature of construction of the building housing the operation.

ECONOMIC ANALYSIS

Information regarding the benefits of EDB use in flour mills was prepared for EPA by Development Planning and Research Associates, Inc. (306).

This report concludes the cancellation of EDB as a spot fumigant in flour mills would result in treatment cost increases of from $4.6 million to $7.7 million depending on the number of general fumigations required to replace EDB. The analysis assumed no production losses with alternate treatments. However, this may not be the case because mills may have to be closed for longer time periods to conduct a general fumigation.

XI. ANALYSIS OF EDB USE IN THE APHIS QUARANTINE PROGRAM

INTRODUCTION

Several agricultural fruit and vegetable commodities are regulated by national and domestic quarantines. These regulations were enacted to protect the importing state from the introduction of new insect or disease pests. Foreign insects invading a new location frequently become more destructive than in their native habitat because of the lack of natural predators, other limiting ecological factors and lack of competition for food sources.

Quarantine measures, including exclusion, inspection, and treatment to eliminate arriving pests, have been utilized as more practical and less costly to the overall agricultural economy than attempts at eradicating pests after they have become established. The cost of eradication of the Mediterranean Fruit Fly, an insect pest requiring EDB treatment, in Florida in 1929-1930 was $7.5 million dollars, not including the value of the host fruits destroyed. It took two years, more than 5,000 laborers, and as many as 1,200 professional quarantine and field inspectors to do the job. In succeeding infestations in 1956, 1962, and 1963, a total of $12 million was expended on treatment of nearly 100,000 acres to successfully eradicate this pest (32).

Without treatment the agricultural production of some areas, both domestic and foreign, would not be permitted to move beyond quarantine lines.

Legal Basis - U.S. Quarantine Treatments

U.S. quarantine treatments are legally mandated by authority of the Plant Quarantine Act of 1912 as amended (7 U.S.C. 151-167) and the Federal

Plant Pest Act (7 U.S.C. 150aa - 150jj) through quarantines, administrative instructions, and regulations issued thereunder. Ethylene dibromide treatments are specifically required under:

7 CFR, Part 318.13-4b (Hawaiian Fruits and Vegetables)

318.58-3d (Fruits and Vegetables from Puerto Rico and the Virgin Islands)

7 CFR, Part 319.56-2e,l, and j (Fruits and Vegetables)

7 CFR, Part 301.64-4a (Mexican Fruit Fly Quarantine).

Quarantine requirements are issued and amended according to procedures specified in the Acts requiring public hearing and lengthy administrative procedures.

Pest Information

EDB is the principal material approved for treating a variety of fresh fruits and vegetables as a quarantine measure against several species of tropical fruit flies, especially - *Ceratitis capitata* (Wied), Mediterranean Fruit Fly; *Anastrepha ludens* (Loew), Mexican Fruit Fly; *A. fraterculus* (Wied), a South American Fruit Fly; *A. suspensa* (Loew), Caribbean Fruit Fly; *A. mombinpraeoptans* (Sein), West Indian Fruit Fly; *Dacus dorsalis* (Hendel), Oriental Fruit Fly; *D. cucurbitae* (Coquillett), Melon Fly; *D. tryoni* (Froggatt), Queensland Fruit Fly; *Rhagoletis cingulata* (Loew), Cherry Fruit Fly and other fruit flies of the genera *Ceratitis*, *Anastrepha*, *Dacus*, and *Rhagoletis* (CFR 319.56 et al.).

EDB Usage

EDB is registered as a commodity fumigant for control of insect pests infesting citrus, pineapples, guavas, papayas, mangoes, cucumbers, bell peppers, bitter melon, cavendish bananas, zucchini squash, string beans, litchi nuts, plums and cantaloupes. It may be used for this purpose only in accordance with the recommendations and instructions issued by the United States Department of Agriculture for various quarantine programs. Fumigations are conducted only with the approval and supervision of proper USDA authorities.

Quarantine treatments were developed to provide effectiveness equivalent to probit 9 (no more than 3 survivors of 100,000 test specimens) (15). Approved EDB fumigation schedules meet this standard. This is one of the factors limiting the number of alternatives available.

EDB quarantine treatments are carried out in gas-tight fumigation chambers constructed and operated in accordance with the provisions of Quarantine 13 (7 CFR 318.13), Quarantine 58 (7 CFR 318.58), Quarantine 56 (7 CFR 319.56), and several State programs. Dosage rates vary from 8 to 16 ounces per thousand cubic feet depending on temperature and fruit load in the chambers. The fumigant is introduced into the chamber in the liquid state onto a suitable heating implement for volatilization. Because of the density of the gas (more than six times heavier than air), forced circulation is required throughout the fumigation period. The exposure period of EDB treatments is two hours from the time the liquid is volatilized. Quarantine specifications call for the use of technical grade EDB of at least 97 percent purity. The gas is removed from the chamber

immediately after the end of the fumigation period. Fresh air is drawn from the outside through the load and the vapor is exhausted through the circulation system to the outside.

In 1977 EDB quarantine treatments were applied to 569.7 million pounds of fruits. Some 83,500 pounds of EDB were used for the treatments. The major quarantine commodities treated to meet import, export, and domestic requirements in the last three years are listed in Table XI-1.

Personnel exposure could occur during application of the liquid EDB into the chamber and in moving and packing the fumigated fruit after treatment. Closed application systems have been successfully tested and are in use in the Florida fumigation facilities. This kind of system eliminates personnel contact with EDB vapor during application and it will be required in other locations.

During tests conducted at the Florida citrus fumigation facilities in 1976, Going and Spigarelli measured breathing zone concentrations of 0.91 ppm (6.9 milligrams per cubic meter) and less (77). EPA measured warehouse levels at the port of Tampa, Florida in November, 1977, of 1.16 ppm (8.99 mg/m^3) in the breathing zone of a fork lift operator and one-third that and less in associated areas. The highest concentrations measured by EPA were in a truck immediately after treatment - 1.95 ppm (15 mg/m^3). A level of 0.62 ppm (4.8 mg/m^3) was measured in a truck at the dock in Tampa 14 hours after fumigation (141). None of these concentrations approach the current Occupational Safety and Health Administration (OSHA), Threshold Limit Value, (TLV) of 20 ppm (275). Closed system application and safer handling practices have reduced the ambient air concentration levels in

Table XI- 1 Commodity treatments with EDB

Origin	Treatment Location	Commodity	Millions lbs. treated 1/	Millions value	Lbs. EDB used 2/
Florida	Florida	Grapefruit			
		Season 74-75	221.0	$ 19.76	20,795
		75-76	255.0	22.8	22,792
		76-77	297.5	29.54	28,628
Hawaii 3/	Hawaii	Papaya CY 74	21.5	13.0	4,588
		FY 77	41.2	11.9	8,809
		Citrus FY 77	.012	.009	3
		Banana FY 77	.005	.001	3
		Litchi FY 77	.067	.037	3
		Cucumber FY 77	.0004	.0001	1
Texas	Texas	Citrus CY 74	83.66	6.90	15,257
		FY 77	85.99	6.92	15,389
Puerto Rico	Puerto Rico	Mango CY 74	.748	.374	98
		FY 76	1.39	.335	197
Dominican Rep.	NY and Puerto Rico	Mango CY 74	.161	.100	20
		FY 76	.347	.832	45
		FY 77	.151	.439	20
Haiti	Haiti	Mango CY 74	2.710	2.00	181
		FY 76	2.389	.573	176
		FY 77	2.940	.933	188
Morocco	Morocco	Clementines			
		CY 74	3.29	.301	270
		FY 77	1.90	.298	231
Belize	Miami	Mango FY 77	.462	.130	90
Israel	New York	Citrus FY 76	.224	.020	50
		FY 77	.664	.079	150

Continued on 2nd page

Continued Table 1

Origin	Treatment Location	Commodity	Millions lbs. treated 1/	Millions value	Lbs. EDB used 2/
Mexico	Mexico	Grapefruit			
		CY 74	10,677	1.000	
		FY 76	5.142	.920	
		FY 77	12.223	1.662	
		Oranges CY 74	55.273	4.975	
		FY 76	11.684	1.040	
		Fy 77	36.830	4.382	
		Tangerines			
		CY 74	50.918	4.583	
		FY 76	33.328	5.232	
		FY 77	66.867	8.826	Mexico Total All Commodities
		Mango CY 74	12.654	6.325	74-27,00
		FY 76	18.826	5.309	76-14,00
		FY 77	22.892	6.619	77-30,000
		Plums FY 75	.678	.306	

1/ USDA, ERS, Foreign Agricultural Trade of the United States.

2/ USDA, APHIS, PPQ, Port and Regional records.

3/ Hawaii quantities from APHIS records. Values from Hawaii Department of Agriculture

the immediate area outside the chambers greatly in the past year. Continuing research on exhaust and aeration techniques is in progress by the Florida Department of Citrus and the USDA, SEA.

Residues in Fruit

As stated in the EPA position paper, a group of Israeli scientists measured residues of EDB in the peel and pulp of grapefruit, oranges, and lemons (5, 36, 46, 47).

These authors used a GLC method based on one developed by Bielorai and Alumot (19) for EDB analysis on fumigated grains. With this method, residues of 1 to 43 ppm were found in the peel and 0.4 to 2.4 ppm in the pulp at four days after fumigation. Residue levels were dependent on the fumigant concentration, length of fumigation, and the temperature and length of the post fumigation aeration. Bussel and Kamburov (36) showed that the residues in both peel and pulp dissipated completely in less than two weeks. Unpublished data compiled by USDA, APHIS, in 1973, indicated levels of 2.52 to 3.04 ppm organic EDB in peel and 0.77 to 0.98 ppm in pulp at 72 hours (304). Similar levels in Florida grapefruit were reported by King. Residues of 1.6 to 2.8 ppm were found in peel and 0.56 to 1.4 ppm in pulp at 72 hours (110). These tests were performed on small quantities of fruit.

Alternatives

Vapor heat: Vapor heat is approved by the USDA, for the treatment of some citrus and mango from Mexican Fruit Fly infested areas and for bell pepper, eggplant, papaya, pineapple (other than smooth cayenne), tomato, and zucchini squash from areas infested with Mediterranean, Oriental and Melon

Fruit Flies. The procedure is a lengthy one as follows:

For Anastrepha Ludens:

Grapefruit, orange, tangerine, mango: Temperature of fruit gradually raised by saturated water vapor at 110°F until approximate center of fruit reaches that temperature in 8 hours, then held at 110°F for 6 hours.

Alternate procedure for orange and tangerine: Temperature of fruit raised by saturated water vapor at 110°F until approximate center of the fruit reaches that temperature in 6 hours, then held at 110°F for 4 hours. The raising of the temperature of the fruit to 110°F must be rapid in the first 2 hours; gradual in the next 4 hours.

For *Ceratitis capitata*, *Dacus dorsalis*, *Dacus cucurbitae*:

Temperature of articles raised by saturated water vapor at 112°F until approximate center reaches that temperature, within a period of time designated by the inspector, held for 8-3/4 hours, then immediately cooled.

Commodities other than papaya should be exposed to 112°F to determine each commodity's tolerance to the treatment before commercial treatments are attempted.

Pretreatment conditioning is an optional prelude to the required treatment, such conditioning being a responsibility of the shipper and in accordance with procedures he believes necessary. For example, it is the practice to condition eggplant at 110°F at 40 percent relative humidity for 6 to 8 hours.

This treatment was among the first to be approved for fruit fly control in the early thirties. However, its high energy demands, length of treatment, (approximately 16 hours) and the impracticality of handling

large volumes of fruit with it were the primary reasons for the development of EDB schedules. The current necessity for resource conservation makes the vapor heat process even more impractical.

Vapor heat has a number of additional disadvantages, primarily its effect on the quality and salability of the product. Sinclair and Lindgren (194) reported vapor heat treatments altered the taste of citrus fruits and produced off-flavors. The heat treatments destroyed the fresh delicate flavor of the naval orange, and the loss of flavor and reduction in acidity of the fruit gave the treated navals a flat taste. Others have reported a "cooked" taste resulting from the treatment. This effect and other effects on quality vary somewhat according to product, maturity, season and accurate application of the process.

Papaya can be treated with EDB or vapor-heat. Vapor-heat treatment would result in damage to blemished or misshaped fruit. Sound fruit could also be damaged if treatment were not perfectly performed. This damage results from rotting of the fruit which occurs from the center of the fruit outward and usually cannot be detected until the fruit is opened by the consumer. This rotting would occur in about 50 percent of the fruit currently treated with EDB.

Consumers may buy fruit in this condition once or twice and then stop buying fresh papayas. The alternative for the papaya processors would be to vapor-heat treat only unblemished and well shaped fruit or about 50 percent of the fruit currently treated with EDB. It may be

possible to increase the percent of fruit acceptable for vapor-heat treatment by more intensive management of papaya groves to insure the production of more sound fruit. More intense management would probably mean increased pesticide and/or growth regulator use so as to reduce the percent of blemished and misshaped fruit. Examination of these alternatives was beyond the scope of this study and would require extensive research by tropical fruit scientists.

According to APHIS treatment schedules, mangoes can be treated with EDB or vapor-heat. In practice, only certain mango varieties can tolerate vapor-heat. Mango varieties currently imported into the United States have not been tested to see if they can withstand vapor-heat treatment. It was assumed that, in the short-run, there would be no alternative to EDB on imported mangoes until testing had been carried out. Over the longer run, foreign producers would probably switch to mango varieties which could be successfully treated with vapor-heat treatments.

Other miscellaneous fruits and vegetables are treated with EDB in relatively small quantities. It was assumed that these could be treated with either vapor-heat or cold treatment with 10 percent loss due to damage.

Cold Treatment

Cold treatment is an accepted method for the treatment of citrus, grapes, apples and pears, and several stone fruits known to be fruit fly hosts from several foreign countries. The method is not approved by Japan for citrus from the United States. Exposing infested fruit to temperatures of 36°F (2.2°C) or below for specified periods results in the death of certain tropical fruit flies. Approved schedules for specific insects and commodities follow:

For *Ceratitis capitata*	10 days at 32°F. or below
	11 days at 33°F. or below
	12 days at 34°F. or below
	14 days at 35°F. or below
For *Anastrepha ludens*	18 days at 33°F. or below
	20 days at 34°F. or below
	22 days at 35°F. or below
For other species of *Anastrepha*	11 days at 32°F. or below
	13 days at 33°F. or below
	15 days at 34°F. or below
	17 days at 35°F. or below
For *Dacus tryoni*......................	13 days at 32°F. or below
	14 days at 33°F. or below

Not all commodities tolerate cold treatment equally well. It is not tolerated by most tropical and some subtropical fruits including mango and papaya. Citrus may be treated from some areas but serious questions arise in the case of grapefruit. Susceptibility to chilling injury varies throughout the season. The big demand for Florida grapefruit in Japan occurs in late spring and early summer, the wrong time of the year to use cold treatment on this commodity. Injury at 32°F is nil until December with an almost exponential increase throughout the rest of the season when Japanese demand is heaviest (87). Damage of this kind could result in loss of about 20 percent of the treated fruit by the time it reaches the consumer. In addition facilites are not available in Florida, Texas, or Mexico, and would have to be constructed and approved before shipments could be initiated.

Other fumigants, including phosphine, methyl bromide, and methyl bromide plus low temperature have been experimentally tested on citrus but none are accepted by Japan. The time required for registration and approval by state or foreign governements precludes their consideration as practical alternatives at this time. During this protracted negotiation time it could reasonably

be expected that Japan would seek other sources of citrus and this market would be lost on a permanent basis. Mexico and Cuba are possible sources of grapefruit for Japan.

Cost of Treatment

The cost of EDB treatment has been $1.60 per 1,000 pounds of product.

Commercial rates for cold treatment are currently $6.25 per 1,000 pounds of fruit. If the transit time is of sufficient duration cold treatment can be accomplished aboard ship.

There are no commercial vapor heat facilities. It was assumed that vapor heat costs would be similar to cold treatment i.e. $6.25 per 1,000 pounds. Due to the location of facilities and energy requirements actual costs could be greater.

Benefits to Specific Areas and Crops

Florida

Japan requires all fresh citrus exports from Florida to be fumigated prior to shipment. EDB is the only substance approved for fumigation of citrus by the Japanese government. Furthermore, EDB is the only substance known to be effective for such fumigation at the present time. Therefore, the entire Japanese market for fresh Florida citrus depends on the continued use of EDB for fumigation.

Since 1972, Japan has become a major market for United States fresh grapefruit exports. Most of the exports have been white seedless varieties produced in Florida. During the 1975-76 and 1976-77 seasons, exports of fresh grapefruit from Florida to Japan represented 73 percent and 82 percent

of total Florida fresh grapefruit exports excluding Canada, respectively. Japanese fresh Florida grapefruit imports represented 15 percent of all fresh grapefruit shipments in 1974-75, 15.5 percent in 1975-76, and 22.4 percent in 1976-77. The packinghouse door value of grapefruit shipped from the U.S. to Japan has averaged $21.0 million (Table XI-5).

Hawaii

The presence of three fruit flies, *C. capitata*, *D. cucurbitae*, and *D. dorsalis* in Hawaii necessitates the quarantine treatment of their fruit and vegetable hosts. Bitter melon, cavendish banana, Hawaiian bluefield banana, apple banana, green cooking banana, cucumber, fresh litchi fruit, pineapple (other than smooth cayenne), string bean, zucchini squash, and papaya are required to be fumigated with EDB for movement from Hawaii. Small amounts of citrus, banana, litchi nut and a few vegetables are occasionally treated. Papaya is the primary fruit treated. More than 41 million pounds of fresh papaya valued at nearly $12 million (FOB, Hawaii) were shipped to the mainland or exported to Japan during FY-1977. Approximately 90 percent of that was shipped to the mainland. Papaya production nearly doubled in Hawaii during the five year period from 1972 to 1976, rising from 25,735,000 pounds to 50,037,000 in 1976 (1). Nearly all papayas produced in Hawaii are utilized as fresh fruit, and only a small percentage (2.6 percent of total production in 1974) is used for processing. Production of papaya for local consumption reached the saturation point some years ago. In recent years about 80 percent of the production has been exported.

All markets available to Hawaii are free of fruit fly infestation and therefore require some kind of treatment. At this time EDB is the only practical treatment accepted by these markets.

Texas

The Mexican Fruit Fly quarantine (7 CFR 301.64) requires the treatment of all host fruits of the Mexican Fruit Fly, *A. ludens*, from infested areas of Texas, if such fruits are moved to or through Arizona, California, Florida, Hawaii; Jefferson, Orleans, Plaquemines, St. Bernard, and St. Charles Parishes in Louisiana; the Virgin Islands of the United States; Puerto Rico; or Guam. Citrus is the primary commodity involved. Nearly 86 million pounds of citrus valued at $6.62 million were treated with EDB to comply with these regulations in FY-1977. This amounts to 15 to 20 percent of the total citrus production in Texas. About 53 percent of the total production is exported from the United States (285).

The major export markets are Europe, Japan and Canada. Although these countries do not require treatment for *A. ludens*, California requires EDB fumigation and the majority of Texas citrus exported to Japan transits California.

If EDB were lost alternate transit routes would have to be found and developed since they are not now available. If all markets now requiring EDB were lost it would place the industry at a disadvantage in trying to compete with producers in other areas for markets that do not require fumigation.

Haiti, Dominican Republic and Belize

These Carribbean and Central American countries export mangoes to the United States. Although the quantities are not large, they are important to these developing countries. Each is attempting to increase its exports to the United States (285).

Mexico

Large quantities of citrus, more than 115 million pounds valued at $14.87 million, were imported from Mexico during FY-1977. In addition nearly 23 million pounds of mangoes valued at $6.6 million was imported. The presence of _A. ludens_, the Mexican Fruit Fly, necessitates quarantine treatment. EDB is the only practical treatment. Although vapor heat is an approved alternative, no facilites are available and the costs in energy would be prohibitive. Since no vapor heat treatments have been conducted for many years detailed cost figures are not available.

If EDB's registration were lost the effect on Mexico's agricultural trade would be immediate and severe. The local market could not absorb the impact of this additional commodity and new markets could not be developed quickly if at all. EDB treatments in Mexico are performed under cooperative agreement with the USDA under APHIS regulations.

ECONOMIC ANALYSIS

This analysis was based on the following assumptions and procedures:

1. Average pounds of fruit treated under the APHIS program for 1974-77 were used as the basis for this analysis.
2. The alternative techniques are vapor-heat and cold treatment.

3. Estimates of fruit damage and loss were made by the EDB Assessment Team based on damage caused by alternative treatments.

4. It was assumed that in the short-term, Japan would not accept fruit treated with any alternative method. Currently, Japan, within their plant protection quarantine program has approved only EDB treatments for grapefruit and papaya.

5. Partial budgeting techniques were used to estimate the impacts of a cancellation of EDB.

6. Price elasticities were used to estimate the short-term price impacts of shifts in quantities of fresh and processed fruit available in the U.S. market.

7. Export value of crops was the value declared for custom purposes. Producer values were packinghouse door returns for fresh and processed fruit, respectively.

Treatment Costs

The loss of EDB for use in the APHIS quarantine program would result in increased treatment costs of $436,100 for importers of fruit and $238,600 for shippers of fruit treated for interstate shipment (Table XI-2). Without exports to Japan, export treatment costs for grapefruit and papaya would decrease by $489,000. The total increased cost would be $185,700.

Table XI-2. Summary of cost changes due to a loss of EDB in the APHIS program a/

Shipment origin	Cost of treatment: With EDB	Cost of treatment: Without EDB	Increase in cost (Decrease)
			1,000 dols.
Export			
Grapefruit	484.0	0	(484.0)
Papaya		0	(5.0)
Total		0	(489.0)
Interstate			
Grapefruit	63.8	249.2	185.4
Papaya	45.1	98.0	52.9
Miscellaneous fruits and vegetables	0.1	0.4	0.3
Total	109.0	445.5	238.6
Imports			
Grapefruit	15.0	58.7	43.7
Mango	20.0	0	(20.0)
Other citrus	140.7	550.0	409.3
Miscellaneous fruits and vegetables	1.1	4.2	3.1
Total	161.8	612.9	436.1
Grand total			185.7

a/ Tables XI-3 and XI-4.

Initially, the cost changes would be borne by the shipper unless the shipper was a cooperative; in the latter case, the cost changes would be passed to producers.

Fruit Markets

Some 303 million pounds of grapefruit would no longer be shipped to Japan if EDB use is cancelled (Table XI-5). About 1.9 million pounds of grapefruit would no longer be imported (Table XI-7). The domestic market would, in the short-run, have to absorb an additional 301 million pounds of grapefruit, about 13 percent of the fresh market.

It is unlikely that Japan would accept an alternative non-chemical treatment to EDB. Japan considers U.S. grapefruit to be a substitute for her domestically produced mandarin orange and imposes a 40 percent import duty on fresh grapefruit during the fresh mandarin season (59). It is not clear to which market the grapefruit previously exported to Japan would go. Markets available for this fruit include the domestic fresh and processed, non-Japanese fresh export, and processed export markets. Currently, returns are highest for fresh markets. Domestic fresh prices have been falling in recent years due to increases in plantings. Shortly after the Japanese started importing fresh grapefruit in significant quantities, U.S. planting increased (70). Increased producer returns apparently encouraged additional plantings. Grapefruit is a perennial crop which takes a number of years to reach full production after planting. Therefore, it is likely that a number of years would be required to reach an equilibrium level in the market place.

Table XI-3. Cost changes due to a loss of EDB for quarantine treatments on grapefruit

Shipment origin	With EDB: Quantity treated a/	With EDB: Cost of treatments b/	Without EDB: Quantity treated c/	Without EDB: Cost of treatments d/	Increase in cost (Decrease)
	Mil. lbs.	1,000 dols.	Mil. lbs.	1,000 dols.	1,000 dols.
Export e/					
Florida	259.2	414.7	0	0	(414.7)
Texas	43.3	69.3	0	0	(69.3)
Total	302.8	484.0	0	0	(484.0)
Interstate f/					
Texas	39.9	63.8	39.9	249.2	185.5
Imports					
Mexico	9.4	15.0	9.4	58.7	43.7

a/ Table XI-1.
b/ Based on EDB treatment cost of $1.60 per 1,000 pounds.
c/ Estimated by EDB Assessment Team.
d/ Based on treatment cost of $6.25 per 1,000 pounds of fruit.
e/ Shipment to Japan.
f/ Shipment to Arizona and California.

Table XI-4. Cost changes due to a loss or EDB for quarantine treatments on various fruits and vegetables.

Commodity and shipment origin	With EDB: Quantity treated a/	With EDB: Cost of treatments b/	Without EDB: Quantity treated c/	Without EDB: Cost of treatments d/	Increase in cost (Decrease)
	1,000 lbs.	1,000 dols.	1,000 lbs.	1,000 dols.	1,000 dols.
PAPAYA					
Export					
Hawaii	3,135	5.0	0	0	(5.0)
Interstate					
Hawaii	28,215	45.1	15,675	98.0	52.9
MANGOES					
Imports					
Puerto Rico	1,069	1.7	0	0	(1.7)
Dominican Rep.	220	0.3	0	0	(0.3)
Haiti	2,680	4.3	0	0	(4.3)
Belize	462	0.7	0	0	(0.7)
Mexico	8,124	13.0	0	0	(13.0)
Total	12,555	(20.0)	0	0	(20.0)
OTHER CITRUS					
Imports					
Morocco	2,590	4.1	2,590	16.2	12.1
Israel	459	0.7	459	2.8	2.1
Mexico	84,957	135.9	84,957	531.0	395.1
Total	88,006	140.7	88,006	550.0	409.3
MISCELLANEOUS FRUITS AND VEGETABLES					
Interstate					
Hawaii	72	0.1	7.2	0.4	0.3
Imports					
Mexico	678	1.1	678	4.2	3.1

a/ Table XI-1.
b/ EDB treatment cost of $1.60 per 1,000 pounds of commodity.
c/ Estimated by EDB Assessment Team.
d/ Treatment cost of $6.25 for cold or vapor-heat per 1,000 pounds of commodity.

Table XI-5. Producer impacts on the quantity shipped and value of grapefruit from a cancellation of EDB use in quarantine producers

Market	EDB available: Quantity a/	EDB available: Value b/	EDB cancelled: Quantity c/	EDB cancelled: Value d/	EDB cancelled: Net reduction in value of product
	1,000 lbs.	1,000 dols.	1,000 lbs.	1,000 dols.	1,000 dols.
EDB treated					
Export	302,757	21,038	0	0	21,038
Interstate	39,868	2,770	31,894	1,887	n.a.
Import	9,347	649	8,412	584	65
Not treated domestic consumption					
Fresh	1,832,086	127,308	2,034,933	120,351	6,957
Processed	3,370,291	65,506	3,470,201	64,100	1,406
Total					29,466

a/ Table XI-1.
b/ 1975-78 average packinghouse door returns from "Citrus Fruits, Production, Use and Value, 1977-78 Crop Year", USDA, ESCS, FrNt 3-1(78).
c/ Estimated by EDB Assessment Team.
d/ Assumes price changes due to increased quantities of grapefruit consumed in the domestic markets. It was assumed that 2/3 of the grapefruit formally exported would be consumed fresh and 1/3 consumed processed. Price elasticities of demand of -.7431 and -.58 were used for the fresh and processed grapefruit, respectively (10,5). The base prices were $0.069488 and $0.019436 per pound respectively for fresh and processed grapefruit.
e/ Includes value of exports plus the change in value of non-treated domestic consumption.

Table XI-6. Impacts on quantity and value of commodities subject to quarantine regulation from cancellation of EDB

Commodity and market	EDB available a/		EDB cancelled		
	Quantity	Value	Quantity b/	Value c/	Net reduction in value of product d/
	1,000 lbs.	1,000 dols.	1,000 lbs.	1,000 dols.	1,000 dols.
Mango					
Import	22,555	3,348	0	0	
Domestic production	17,417	2,585	17,417	7,274	-4,689
Consumption	39,972	5,933	17,417	7,274	-4,689
Papaya					
Export	3,135	1,245	0	0	1,245
Mainland	28,215	11,205	15,675	15,101	-3,896
	31,350	12,450	15,675	15,101	-2,651
Citrus other than grapefruit					
Import	88,006	20,027	79,204	18,024	2,003
Interstate	12	3	11	3	0
	88,018	20,030	79,215	18,027	2,003
Miscellaneous fruits and vegetables					
Import	678	306	610	275	31
Interstate	72	38	65	34	4
	750	344	675	309	35

a/ Table XI-1.
b/ Estimated by EDB Assessment Team based on assumptions in text.
c/ Assumes price elasticity of demand for mango and papaya of -.31 and no price impacts on other commodities. The base prices were $0.1484 and $0.3971 per pound respectively for mangoes and papayas. Base prices were not included for other commodities because price changes were not expected.
d/ Does not include the value of mangoes no longer imported because an analysis of other country markets was beyond the scope of this study.

Table XI-7. Balance of payments impacts from a cancellation of EDB use in the APHIS quarantine program

Commodity and market	EDB available		EDB cancelled		Negative impa on balance of payments (positive)
	Quantity	Value	Quantity	Value	
	1,000 lbs. a/	1,000 dols. a/	1,000 lbs. b/	1,000 dols. b/	1,000 dols.
Grapefruit					
Exports	302,757	27,616	0	0	27,616
Imports	9,347	1,194	7,478	955	239
Total		28,810		955	27,375
Papaya					
Exports	3,135	1,245	0	0	1,245
Mango					
Imports	22,555	8,194	0	0	(8,194)
Other citrus					
Imports	88,006	20,027	79,204	18,024	(2,003)
Miscellaneous fruits and vegetables	678	306	610	275	(31)
Total					18,384

a/ Table XI-1.

b/ Tables XI-4 and XI-5.

The loss of the Japanese market is expected to have a price impact in the domestic market. It is expected that a portion of the fresh grapefruit previously shipped to Japan would be consumed fresh and a portion processed. Actually, the lower quality domestic fresh grapefruit would probably be processed and the grapefruit previously exported to Japan would enter the fresh market. Some of the grapefruit may be exported to other countries in fresh and processed forms. However, to simplify this analysis, it was assumed that fresh grapefruit previously shipped to Japan would be consumed domestically. This assumption may bias the estimates, but there is no information indicating the direction of the bias. Information on grapefruit consumption, both domestic and foreign, suggested that, given current market conditions, U.S. exporters could not increase their returns by increasing exports (70).

Several scenarios are presented to provide a range of estimates and the likely impact of a loss of EDB on grapefruit producers. To estimate the impact a price elasticity of demand of -.7431, based on 1971-77 quarterly data, was used (286). The most likely loss to U.S. grapefruit producers would be $29.4 million. This assumed two-thirds of the grapefruit previously exported to Japan went to the domestic fresh market and one-third to processed (Table XI-5).

A minimum impact of $26.5 million would occur if all fresh grapefruit previously exported to Japan went to the processed market. This estimate was based on the 303 million pounds moving into the processed market with a base price of $0.019436 per pound and an elasticity demand of -.58 (229). A maximum impact of $33.0 million would occur if all fresh

grapefruit previously exported to Japan went to the fresh market. This estimate was based on the 303 million pounds moving into the fresh market,

The loss of grapefruit due to cold treatment in the interstate market was not considered in the price impact estimated above. If Texas producers were to lose 8.0 million pounds of grapefruit (Table XI-5), then the impact to other domestic producers would be reduced and Texas producers would have significant reductions in the quantity of grapefruit marketed and in revenue received. The impacts of these losses to Texas producers needs to be examined in more detail.

In the short-run, domestic consumers would have higher quality fresh grapefruit at a lower price. However, over the longer run, it is expected that some producers would shift their resources to alternative uses due to decreased revenues. With a reduction in supplies available, producer and consumer prices would rise. If there are significant economies of scale (lower cost per unit of output) to increased grapefruit production, then the reduction in production would result in producers moving back up their cost curves and consumers would pay more for grapefruit than while EDB was available to treat exported grapefruit. The magnitude of consumer impacts has not been evaluated in this study.

Without EDB available, it was assumed that mangoes would no longer be imported into the United States until varieties tolerant to vapor heat were produced. This would result in about a 56 percent reduction in the quantity of mangoes available for domestic consumption. No published or unpublished estimates of price elasticities of demand for mangoes have

been located. But if one assumes that the consumer demand for mangoes is similar to avocadoes, the price elasticity of demand of -.31 for avocadoes could be used for mangoes. Based on this elasticity it was estimated that grower revenue for domestically grown mangoes would increase from a current $2.6 million to $7.3 million or by $4.7 million (Table XI-6). Consumers would pay more for fewer mangoes. Over the longer run, domestic production probably would increase or foreign exporters would test the currently imported varieties and/or would plant varieties which would withstand vapor-heat treatment.

Papaya producers would lose the $1.2 million current value due to loss of the export market to Japan (Table XI-6). The reduction in interstate shipments of papaya if EDB use is cancelled would have price impacts. There is no price elasticity estimate available for papaya, but using the price elasticity of demand of -.31 for avocadoes, producers would have an income gain of $2.6 million. Consumers would pay higher prices for a smaller quantity of papaya.

Importers of citrus other than grapefruit would have a reduction in the value of product shipped of $2.0 million. These impacts would primarily fall on importers from Mexico since most other citrus is imported from Mexico (238). The importers normally pay for the treatments. It is not known if they could pass the cost back to producers. These impacts would be of a relatively small magnitude and there would be no expected price impacts.

There have been relatively small quantities of miscellaneous fruits and vegetables treated with EDB. There were no anticipated price impacts to the producers or consumer of these commodities.

It was expected that over the long run there would be adjustments by domestic and foreign producers to reduce some of the price impacts shown here. However, it is clear that unless there are technological advances in fumigation techniques for quarantine purposes, there would be a reduction in net income to domestic producers of all these commodities except mangoes. Consumers would also have a reduction in welfare for all affected commodities except possibly for consumers of grapefruit.

Balance of Payments Impacts

The cancellation of EDB usage in the APHIS quarantine programs would have an adverse impact on the U.S. balance of payments. This impact, estimated at $18.4 million, would eventually be borne by the consumer (Table XI-7). The major factor would be the $27.6 million loss from grapefruit exports to Japan. Papaya exports, also to Japan, valued at $1.2 million, would be lost. Mangoes, valued at $8.2 million, would no longer be imported. Other commodities previously treated with EDB would be damaged, resulting in a $2.0 million positive impact on the balance of payment position. This loss of imports would partly offset the loss of exports. However, the consumer would either have to substitute another less acceptable product or pay higher prices for domestic produce.

Social Impact

Failure to re-register EDB would have a direct adverse affect on the lives of the people involved in the Hawaiian papaya industry. There are about 125 growers who cultivate approximately 2,000 acres of papaya in

Hawaii county, the major production area. Most of these cultivate small plots averaging about 15 acres. They and the 350 farm laborers and processing plant employees and their families gain their livelihood from the papaya industry (90). Without EDB they would have to turn to less practical crops. The papaya export market is essential to their economic and social well-being.

LIMITATIONS

1. Data unavailability on the commercial use of the alternative treatments techniques, forced the assumption that experimental results would be equal to commercial treatments for effectiveness and commodity damage. There is some evidence indicating that this is unlikely since commodity trade between fruit fly infested and uninfested areas developed rapidly only after the approval of EDB treatments. Prior to the introduction of EDB, the alternatives, cold treatment and vapor-heat, were approved for the APHIS programs.

2. Currently, there are no commercial vapor-heat facilities available. This analysis assumed they would be available. Until they become available, interstate shipments of papaya would stop.

3. Price elasticities of demand are usually not estimated for the range of quantity changes estimated to occur in this study. Therefore, the economic impacts estimated in this study only give an indication of the direction and magnitude of price changes. The actual economic impacts as a result of an EDB cancellation could be much larger or smaller depending on how consumers react to the higher prices.

4. Long-term impacts are certain to be significant for the fruit producers involved in this study. Growers would probably adjust the number of fruit trees and thus output. These adjustments could be expected to change the results estimated in this analysis.

XII. ANALYSIS OF EDB USE ON PEANUTS

INTRODUCTION

EDB is used to control nematodes on about 17 percent of U.S. peanut acreage in the major peanut producing regions. Peanuts are produced on a significant scale in 10 States as illustrated in Figure XII-1. Georgia is the major peanut producing State, producing peanuts valued at $309 million or about 42 percent of the value of the U.S. peanut crop. Alabama and Texas are the second and third ranked States producing peanuts valued at $100 million and $88 million, respectively. The total U.S. peanut crop has a value of about $720 million (251).

Pest Information

Nematodes are one of the major limiting factors in peanut production in the southeastern United States. This is due in part to the fact that nematodes which attack peanuts cannot be seen easily without the aid of a microscope and to their habit of feeding on the underground parts of the plant making it difficult to discover their presence. The two major groups which affect peanuts are ectoparasites which feed externally and endoparasites which feed internally on the roots, pegs, and pods. Continuous feeding by either group causes various disorders. The principal nematodes affecting peanuts in the Southeast are the northern root-knot, peanut root-knot, lesion, sting, ring and stubby root (292).

Northern Root-Knot Nematode (*Meloidogyne hapla*) enters and feeds inside the peanut roots, pegs and pods. This nematode causes a formation of

FIGURE XII-1

Major Peanut Producing States

small galls and rapid root growth. Excessive matting of lateral roots, poor nodulation and rootlets on the pegs are characteristics of the disease.

Peanut Root-Knot (*Meloidogyne arenaria*). This nematode is found on peanuts in the Southeast, predominantly in Alabama, Georgia, and Florida, and in Texas. However, it is a much more devastating pest than the northern root-knot. This nematode attacks the roots, pegs, and pods, causing large galls that are rough and knotty in appearance. Plants infected early are stunted and quite frequently die before the end of the growing season.

Lesion Nematode (*Pratylenchus brachyurus*). Georgia, Virginia, and North Carolina have reported frequent damage to peanuts from this nematode, while Alabama and Texas have reported occasional damage. Lesion nematode damage is characterized by small discolored lesions on the pods and pegs. The real damage from lesions occurs when soil-borne organisms such as bacteria and fungi invade the lesions caused by the nematode. They accelerate decay of pegs and kernels. This decay not only takes a heavy toll of pods at harvest but also greatly affects quality of the pods which are harvested.

Sting Nematode (*Belonolaimus longicaudatus*). The sting nematode is one of the most devastating nematode parasites of peanuts wherever it occurs. This nematode is most commonly found in light sandy and sandy loam soils. North Carolina and Virginia have areas that are heavily infested and have experienced heavy losses where no control has been practiced. Plants affected by this nematode are markedly stunted and yellow. Roots of affected plants become discolored and sparse, the lateral roots are frequently destroyed and pods are discolored. Yields are low and quality is poor from affected areas.

Ring (Criconemoides) and Stubby-Root (Trichodorus sp.). These two nematodes are probably responsible for some losses in yield and quality throughout the entire peanut belt. Symptoms are similar to those caused by the sting nematode.

Current Use of EDB

EDB provides for excellent control of the root-knot nematode. Even though in the past the majority of EDB used on peanuts has been on a broadcast basis at a cost of $36 per acre, EDB can be equally effective as a row treatment of 2.5 gallons per acre at a cost of $16.75 per acre. EDB EC90, an emulsion formulation of ethylene dibromide that can be used as a row injection or broadcast treatment at the time of planting, probably will replace DBCP in the southeastern States (60, 182, 228). EDB EC90 is now labelled under 24C for use on peanuts at planting time in Alabama, Florida, Georgia, South Carolina and Virginia. In addition, it has been demonstrated that the combination of EDB with chloropicrin (72-27) at 1 gallon/acre row injected at the time of planting gave good nematode control plus control of the pod rot organisms Rhizoctonia, Sclerotium rolfsii and Pythium species (291).

Prior to the cancellation of DBCP usage on peanut fields, EDB was used on about 1,590 acres, with total EDB usage of about 39,000 pounds active ingredient (294). Since the suspension in 1977 and subsequent cancellation in 1978 of DBCP usage on peanuts, EDB has become the preferred nematicide for use on peanut fields in several States. EDB was considered the preferred alternative to DBCP in the DBCP analysis. The availability of EDB as an alternative to DBCP minimized the potential impact of the DBCP cancellation

(269). The EDB Assessment Team projected current acres treated with EDB to be 257,390 acres, for a total projected EDB usage on peanut fields of 4,118,240 pounds active ingredient based on application rates of 1 gallon per acre (16 lbs. a.i.) in Alabama, Florida, Georgia, South Carolina and Virginia and 2.5 gallons per acre, (12 lbs. a.i.) in Mississippi, North Carolina, and the Southern Plains (Table XII-1).

These projections of producers shifting from DBCP to EDB are uncertain. Since there are several alternatives to DBCP, producers shifting from DBCP may choose a nematicide other than EDB. However, in those States where EDB is registered for use, at planting use, EDB is the least expensive alternative to DBCP. It is also as efficacious as DBCP under most soil conditions against those nematodes causing economic loss to peanuts. Therefore, the rational choice for producers would be to use EDB at planting time rather than other nematicides.

Application Methods, Time, Rate and Cost

EDB + chloropicrin is applied at the rate of 30 to 72 pounds EDB (a.i.) per acre at a cost of \$13.75 to \$33.00 per acre plus \$3.00 per acre for application. Two methods of application are used: (1) Row chisel injection 8-10 inches below the soil surface; (2) Overall injection 8 to 10-inches deep with chisels 12 inches apart, application can be made only preplant with the regular formulations of EDB thus requiring an extra trip over the field at an added cost of \$3.00 per acre and a waiting period of 10 to 14 days before planting. However, the EDB EC90 formulation is applied at planting in the States with 24C registrations. If planting is delayed beyond May 1, yield losses can be expected to occur. Agricultural researchers at the University of Georgia estimated that a delay in planting from May 1 to June 1 would result in yield losses of 20 percent (133). For this report it was assumed

Table XII-1 Annual economic impact of the cancellation of EDB use on peanuts

Region and State	Acres planted: 1975-1977 a/	Acres treated: with EDB in 1977 b/	Projected increase in acres treated b/	Total estimated acres treated with EDB	Increase in nematode control cost c/	Value of production loss d/	Decrease in grower revenues: Total	Decrease in grower revenues: Per acre
					$1,000			
Southeast								
Alabama	212,700		114,700	114,700	1,246	4,449	5,695	49.65
Florida	63,000		32,000	32,000	347	1,364	1,711	53.47
Georgia	527,000		104,720	104,720	927	5,135	6,062	57.89
Mississippi	8,500		2,750	2,750	4	0	4	1.45
Total	811,200		254,170	254,170	2,524	10,948	13,472	53.00
Mid Atlantic								
N. Carolina	168,000	840		840	-2	0	-2	-2.38
S. Carolina	15,800	100		100	0	2	2	20.00
Virginia	104,000	500		500	3	16	19	38.00
Total	287,800	1,440		1,440	1	18	19	11.80
Southern Plains								
Oklahoma	124,700	150		150	1	0	1	6.67
Texas	309,000		1,630	1,630	13	0	17	10.43
Total	433,700	150	1,630	1,780	14	0	18	10.11
All regions	1,532,700	1,590	255,800	257,390	2,539	10,966	13.509	52.47

a/ 1975-77 Average. "Crop Production 1977 Annual Summary," USDA, ESCS, CrPr 2-1 (78) January 1978

b/ Estimated by EDB Assessment Team.

c/ Table XII -2

d/ Table XII -3

that peanut yields would decrease 5 percent per week of planting delay. A weighted average production loss based on the percent of the crop planted by week was calculated. For Georgia the reduction in yield from a delay of two weeks in planting was estimated at 7.5 percent while in the other southeastern States and Texas it was estimated at 8.0 percent (267).

The Peanut Disease Loss Committee placed the 1977 losses from all nematodes at an average of 5.8 percent over the area (294). In 1977 approximately 57 percent of peanut acreage was treated. 19 percent was treated with DBCP, 27 percent treated with granular nematicides, 1.5 percent was treated with ethylene dibromide, and 9 percent was treated with D-D or Telone II (294). In the Southeast the endoparasitic root-knot nematode is the major problem. This nematode is more difficult to control than the ectoparasitic nematodes. Alternative fumigants (D-D or Telone II) would be required on a portion of the peanut acreage to control these nematodes. Agricultural scientists estimated that in Georgia 30,000-40,000 acres would be treated with EDB in 1978 (228). For Alabama, Florida, and Mississippi, the scientists estimated that approximately 90,000 acres that were treated with DBCP in 1977 will be treated with EDB in 1978 (60, 182). The remaining acreage in the Southeast treated with DBCP would be treated with a contact nematicide (120, 214). The ectoparasitic nematodes are the major nematode problem in the mid-Atlantic states of North Carolina, South Carolina and Virginia. The granular nematicides, carbofuran, fensulfothion, ethoprop, aldicarb, and fenamiphos, could be substituted for all fumigants with a slight yield reduction of approximately 6 percent and increased costs of about $8.00 per acre.

Alternatives

There are several viable registered alternatives to EDB for use on peanut fields. The alternatives are less efficacious against some or all nematode species, are less efficacious under certain soil moisture conditions, require different cultural practices due to phytotoxic effects, and/or are more costly to use. The alternative liquid fumigants are Telone II and D-D. At current prices, EDB costs $8.50 per acre (1 gallon, 16 lbs a.i. per gallon) or $13.75 per acre (2.5 gallons, 12 lbs a.i. per gallon) depending on the formulation used. Telone II costs $24.00 per acre (6 gallons at $4.00 per gallon), and D-D costs $25.00 per acre (10 gallons at $2.50 per gallon) (Table XII-2). Due to phytotoxic effects on the emerging peanut plant, all liquid fumigants except the EDB formulation applied at 1 gallon per acre (16 lbs a.i.) are applied 10 to 14 days prior to planting in a separate field operation.

The most viable registered granular alternatives are Furadan, Dasanit, Mocap, Nemacur, and Temik, which are applied at planting. At current prices, granular nematicides cost $21.00 per acre (3 lbs a.i. per acre) or $14.00 per acre (2 lbs a.i. per acre) depending on the application rate. These contact nematicides, with the exception of Temik, cost about $7.00 per pound a.i.; Temik costs about $12.00 per pound a.i.; however it serves a dual purpose because it is a nematicide and insecticide. It was assumed that $7.00 of the price paid for Temik went for nematode control and the remainder as an insecticide because there was no reasonable alternative method to allocate nematode and insect control.

Table XII-2. Increase in nematicide control cost if alternative nematicides are used to replace EDB on peanuts

Region	With EDB		Distribution of acreage by alternative nematicide category						Increase in control costs
			Granular			Fumigant			
	Acres treated a/	Control costs b/	Percent acres treated a/	Acres treated	Control costs c/	Percent acres treated a/	Acres treated	Control costs d/	
		$1,000			$1,000			$1,000	
Southeast									
Alabama	114,700	975	60	68,820	964	40	45,880	1,257	1,246
Florida	32,000	272	60	19,200	269	40	12,800	351	348
Georgia	104,720	890	75	78,540	1,100	25	26,180	717	927
Mississippi	2,750	46	60	1,650	23	40	1,100	27	4
Total	254,170	2,183		168,210	2,355		89,960	2,352	2,524
Mid-Atlantic									
N. Carolina	840	14	100	840	12	0	0	0	-2
S. Carolina	100	1	100	100	1	0	0	0	0
Virginia	500	4	100	500	7	0	0	0	3
Total	1,440	19		1,440	20		0	0	1
Southern Plains									
Oklahoma	150	2	100	150	3	0	0	0	1
Texas	1,630	27	0	0	0	100	1,630	40	13
Total	1,780	29		150	3		1,630	40	14
All regions	257,390	2,231		169,800	2,378		87,590	2,392	2,539

a/ Acres treated with EDB and its alternatives were estimated by the EDB Assessment Team. In making these estimates product labels, State recommendations, efficacy of alternative nematode controls, control costs, and estimates made in the DBCP Report (3) were considered.

b/ Control costs with EDB were based on the use of 1.0 gallon of EDB per acre (16 pounds a.i. per gallon) at planting, at $8.50 per gallon for Alabama, Florida, Georgia, South Carolina and Virginia, and 2.5 gallons of EDB per acre (12 pounds a.i. per gallon) at $5.50 per gallon for $13.75 per acre plus $3.00 per acre for additional field operation due to planting delay for a total cost of $16.75 per acre for the remaining States.

c/ Granular control costs were based on an application rate of 3 pounds a.i. per acre in Oklahoma and Texas and 2 pounds a.i. per acre in the remaining States. Granular materials cost $7.00 per pound a.i. giving a cost of $21.00 per acre in Oklahoma and Texas, and $14 per acre in the remaining States, less $3.00 per acre for those States applying EDB 10-14 days prior to planting.

d/ Fumigant control costs were based on 60 percent Telone II (6 gallons per acre at $4.00 per gallon), and 40 percent D-D (10 gallons per acre at $2.50 per gallon) for a total of $24.40 per acre. In Mississippi [illegible] Texas [illegible] per acre for an additional field operation [illegible] 40.

Table XII-3. Value of production if alternative nematicides are used to replace EDB on peanuts.

Region and State	With EDB			Alternative to EDB: Granular				Alternative to EDB: Fumigant				Value of loss of production without EDB
	Yield per acre a/	Production on treated acres b/	Value of production c/	Reduction in yield d/	Yield per acre	Production	Value of production	Reduction in yield d/	Yield per acre	Production	Value of production	
	pounds	1,000 pounds	$1,000	percent	pounds	$1,000 pounds	$1,000	percent	pounds	1,000 pounds	$1,000	$1,000
Southeast												
Alabama	2,434	279,180	56,394	7.8	2,244	154,432	31,195	8.0	2,239	102,725	20,750	4,449
Florida	2,673	85,536	17,278	7.8	2,464	47,309	9,556	8.0	2,459	31,475	6,358	1,364
Georgia	3,146	329,449	66,549	7.8	2,901	227,844	46,025	7.5	2,910	76,184	15,389	5,135
Mississippi	1,304	3,586	724	0	1,304	2,152	435	0	1,304	1,434	290	0
Total		697,751	140,945			411,737	87,211			211,818	42,787	10,948
Mid-Atlantic												
North Carolina	2,239	1,881	380	0.0	2,239	1,881	380	--	--	--	--	0
South Carolina	1,744	174	35	6.0	1,639	164	33	--	--	--	--	2
Virginia	2,838	1,419	289	6.0	2,668	1,344	271	--	--	--	--	16
Total		3,474	702			3,389	684	--	--	--	--	18
Southern Plains												
Oklahoma	2,557	383	77	0.0	2,557	383	77	--	--	--	--	0
Texas	1,969	3,209	648					0	1,969	3,209	648	0
Total		3,592	725			383	77			3,209	648	0
All regions		704,817	142,372			435,509	87,972			215,027	43,435	10,966

a/ Yield per acre for Alabama, Florida, Georgia, South Carolina and Virginia was the weighted average yield for 1975-1977 per "Crop Production, 1977 Annual Summary" USDA, ESCS, CrPr 2-1(78), January 1978; for Mississippi and North Carolina was the weighted average yield for 1975-1977 less 8 percent to allow for planting delays beyond the optimal planting time with the use of EDB: See Table XII-2; and for Oklahoma and Texas it was assumed that EDB was applied to adequate soil moisture areas only giving yields based on information "Firm Enterprise Data System", USDA, ESCS, CED and Oklahoma State University less 8 percent to allow for planting delays beyond the optimal planting time.

b/ Treated acres listed in column 1, Table XII -2.

c/ 1975-1976 weighted average price of 20.2¢ per pound per "Crop Values, 1975, 1976, 1977," USDA, ESCS, CrPr 2-1(78) January 1978.

d/ Estimated by the EDB Assessment Team based on estimates developed in "Economic and Social Inputs of Cancelling Use of DBCP as a Pesticide for all Registered Use Sites with Known Current Usage," USDA and USEPA, March, 1978.

Table XII-4 Effects of delayed planting on peanut yields if EDB is not available for nematode control in Southeast Georgia

Week based on 1976 dates	With EDB available: Acreage planted during week a/	With EDB available: Index of yield by planting dates b/	Alternative fumigants: Acreage planted during week c/	Alternative fumigants: Index of yield by planting date b/
	percent			
April				
5-11	2.0	100	—	—
12-18	13.5	100	—	—
19-25	24.5	100	2.0	100
26-2	18.5	100	13.5	100
May				
3-9	22.5	95	24.5	95
9-16	8.5	90	18.5	90
17-23	10.5	85	22.5	85
24-30	—	—	8.5	80
31-6	—	—	10.5	75
Total	100.0	96.4 d/	100.0	89.2 e/
Decrease in yield index				7.5 f/

a/ Average 1975-76 planted acreages based on information from "Weekly Weather and Crop Bulletin", published jointly by the U.S. Department of Commerce, Environmental Data Service, NOAA and the U.S. Department of Agriculture, Statistical Reporting Service.

b/ Based on research by McGill (Georgia) which indicated that if planting was completed by May 1 there would be no yield losses while delaying planting until June 1 resulted in a 20 percent yield loss. For this study a linear loss relationship of 5 percent per week of planting delay was assumed starting with the first week of May.

c/ When alternative fumigants are used to replace EDB planting is delayed about 2 weeks to avoid phytotoxic effects of these materials. The average 1975-76 percent of acres planted was shifted to reflect this 2 week delay.

d/ Weighted average yield index by acres planted during weeks with EDB available.

e/ Weighted average yield index by acres planted during week with alternatives to EDB.

f/ Estimated percent decrease in peanut yields due to planting delays without EDB available.

Table XII-5. Effects of delayed planting on peanut yields if EDB is not available for nematode control in Alabama, Florida, Mississippi and Texas

Week based on 1976 dates	With EDB available: Acreage planted during week a/	With EDB available: Index of yield by planting dates b/	Alternative fumigants: Acreage planted during week c/	Alternative fumigants: Index of yield by planting date b/
	percent			
April				
5-11	—	—	—	—
12-18	8.0	100	—	—
19-25	32.5	100	—	—
26-2	12.5	100	8.0	100
May				
3-9	18.0	95	32.5	95
9-16	10.5	90	12.5	90
17-23	7.0	85	18.0	85
24-30	11.5	80	10.5	80
31-6	—	—	7.0	75
June				
7-13	—	—	11.5	70
Total	100	94.7 d/	100	87.1 e/
Decrease in yield index				8.0 f/

a/ Average 1975-76 planted averages based on information from "Weekly Weather and Crop Bulletin", published jointly by the U.S. Department of Commerce, Environmental Data Service, NOAA and the U.S. Department of Agriculture, Statistical Reporting Service.

b/ Based on research by McGill (Georgia) which indicated that if planting was completed by May 1, there could be no yield losses, while delaying planting until June 1 would result in a 20 percent yield loss. For this study, a linear loss relationship of 5 percent per week of planting delay was assumed starting with the first week of May.

c/ When alternative fumigants are used to replace EDB planting is delayed about 2 weeks to avoid phytotoxic effects of these materials. The average 1975-76 percent of acres planted was shifted to reflect this 2 week delay.

d/ Weighted average yield index by acres planted during week with EDB available.

e/ Weighted average yield index by acres planted during week with alternatives for EDB.

f/ Estimated percent decrease in peanut yields due to planting delays without EDB available.

Crop Rotation

Crops commonly used in rotation with peanuts are corn, cotton, small grains, and to a lesser extent, milo. Ectoparasitic nematodes in the genera *Pratylenchus* (lesion), *Trichodorus* (stubby root), and *Belonolaimus* (sting) are parasitic to all these crops, consequently the beneficial effect of any of these crops for reducing nematode numbers and damage is eliminated. Inclusion of cotton as a rotation crop in fields where the peanut root-knot nematodes (*M. arenaria* or *M. hapla*) are present may be expected to reduce populations of these nematodes since cotton is a non-host. These serve as examples of the complications that occur under actual field conditions and eliminates for the most part the practical effective use of rotations in peanuts as the only means of nematode control (79, 182, 189).

Beneficial Effects

There is evidence that application of EDB + chloropicrin results in good control of *Pythium* and importantly, for peanuts, *Rhizoctonia solani* (292). *Rhizoctonia solani* is one of the main components of the *Rhizoctonia* - *Pythium* - *Fusarium* pod rot complex in peanuts. It is the principal disease causing agent in the complex in North Carolina, Virginia, Georgia, and Alabama. EDB + chloropicrin is recommended in North Carolina for the reduction of the pod rot complex. 1977 tests in North Carolina also showed this combination to be an effective control for *Sclerotium rolfsii* (291).

Non-Target Effects of Alternatives

The use of organophosphates as replacements for EDB carries disturbing implications. Because of the general ineffectiveness of organophosphates against the peanut root-knot nematode, *M. arenaria*, they should be expected to select for these nematodes when applied to fields with mixed populations of these nematodes and other species more sensitive to the organophosphate. In contrast, the broader spectrum activity of EDB which includes *M. arenaria* and *Hoplolaimus columbus* does not present this possible problem (11, 182).

ECONOMIC ANALYSIS

The estimated short-run (one year) economic impact of a possible EDB cancellation on peanuts was based on the following procedures and assumptions:

1. U.S. 1975-77 planted acres, yield per planted acre, and price received by farmers were used in this analysis. The 3-year average price received by farmers was 20.2 cents per pound.

2. The price of alternative nematicides would not change and they would be available in sufficient quantities for use on EDB treated peanut acreage.

3. Alternative nematicides and their usage rates were specified by the EDB Assessment Team. These alternatives were assumed to be the most viable if EDB were not available. In making these determinations, product labels, State recommendations, efficacy of the alternative nematicides, and treatment costs per acre were considered.

4. EDB is applied by chisel injection into the soil annually at planting time in Alabama, Florida, Georgia, North Carolina, South Carolina,

and Virginia and two weeks prior to planting in the remaining States.

5. In those States where EDB was applied at planting, an application cost of $3.00 per acre was assumed for alternative fumigants becuse they must be applied in a separate field operation prior to planting.

6. Partial budgeting techniques were used to estimate the short-term impact of an EDB cancellation.

Results

The total producer impact due to the cancellation of EDB use on peanuts would amount to $13.5 million: $11.0 million in production losses and $2.5 million in increased nematode control cost (Table XII-1). The area of significant impact would be in the Southeast with increased nematode control costs and revenue losses estimated at $13.4 million. The impacts on other regions would be minimal.

The information generated in this study indicates the loss of EDB would have a minimum direct impact on the consumer. The total value of increased costs and value of production of $13.5 million impact compared to a crop value of about $720.0 million is less than 2 percent of the value of the peanut crop to producers. These short term impacts probably would not be large enough to have significant consumer impacts.

LIMITATIONS

This study has several limitations which could influence the estimates:

1. The estimated acreage treated with EDB was influenced by the cancellation of DBCP for use on peanuts. Although there was information indicating that producers were using EDB in increased quantities in 1978,

the resulting yields after a year of EDB field use would determine whether producers would continue to use EDB.

2. The acreage distribution of alternative nematicides applied at planting to replace EDB was estimated by the EDB Assessment Team. Actual producer usage would depend on producer experience in using the alternatives.

3. Production loss estimates were made by the Assessment Team based on results from experimental plots. Field trials could result in different production losses.

4. It was assumed that prices of alternative nematicides would not change if EDB were cancelled and they would be available in sufficient quantities.

XIII. ANALYSIS OF EDB USE ON COTTON

INTRODUCTION

EDB is registered for use on cotton throughout the Cotton Belt. Cotton is a principal crop in the southern States, having an 1975-77 average production value of $3.3 billion (244). Figure XIII-1 presents the major cotton producing States. Texas and California are the major cotton producing States, having crops with a value of $1,061 million and $787 million, respectively. This represents about 56 percent of the value of United States cotton production. Arkansas, Arizona, Louisiana, New Mexico and Mississippi have crops valued from $100 million to $500 million. Nevada, Kentucky and Virginia all produced a crop having a value of less than $1.0 million. The remaining States producing cotton on a commercial scale have had crops with values greater than $10 million and less than $100 million.

Pest Information

The key nematode in crop losses in cotton is the cotton root-knot nematode, *Meloidogyne incognita* by reason of its reproductive and survival capacity, wide host range, and the fact that it is found in all the cotton producing States. Other nematodes which cause significant economic losses in one or more States are the sting nematodes, *Belonolaimus* spp., the lance nematodes, *Hoplolaimus columbus* and *H. galeatus*, the reniform nematode, *Rotylenchulus reniformis*, and the stunt nematodes, *Tylenchorhynchus* spp. (23).

Other genera occasionally associated with damage to cotton include lesion nematodes, _Pratylenchus_ spp., spiral nematodes, _Helicotylenchus_ spp., and dagger nematodes, _Xiphinema_ spp.

In addition to crop losses directly attributable to these nematodes. root-knot, sting, and stunt nematodes significantly increase the damage caused by _Fusarium_ wilt, producing a disease complex commonly referred to as _Fusarium_ wilt-nematode disease (167).

EDB Usage

EDB is applied to cotton fields prior to planting. It is usually injected 8 to 12 inches below the soil surface. When injected with chisels set 12 inches apart over the entire area it is said to be applied overall. In-the-row application is made with one or two chisels near the center of the row. Cotton rows are commonly 36 to 42 inches apart unless skip row planting is practiced. The amount applied may vary from 45 to 90 pounds a.i./acre for overall treatment to 24 to 30 pounds a.i./acre for in-row treatments. The in-row treatment is usually accomplished with a "hipper ripper". The amount used depends on local conditions, degree of soil infestation, and the economics of production. Approximately 721,800 pounds of EDB are applied per year to treat 24,060 acres of cotton (Table XIII-1).

In addition to those acres treated with EDB in past years, it is expected that about 31,500 acres of cotton fields which were previously treated with DBCP would be treated with EDB in 1978. EPA in a recent decision has suspended use of DBCP on cotton. However, recent price increases for DBCP from about $8.00 per gallon to about $22.00 per gallon make it financially

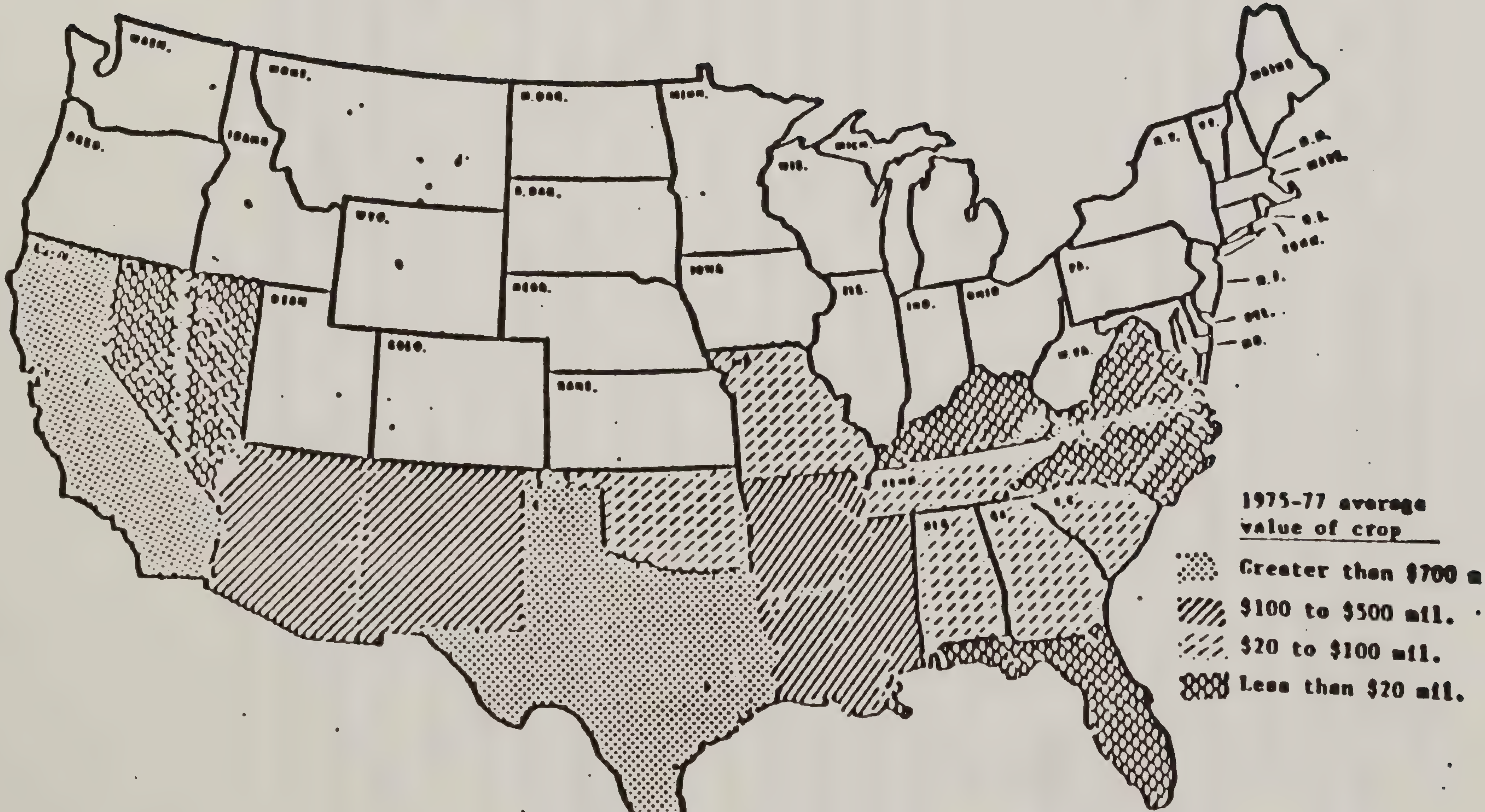


Figure XIII-1. Cotton Producing States

Table XIII-1. Geographic regions involved in upland cotton production

States	Total acreage planted 1000 acres	Acres a/ treated with EDB 1976
Alabama	400	---
Arizona	468	60
Arkansas	1,000	5,000
California	1,340	7,000
Florida	5.5	
Georgia	200	---
Kentucky	.8	5,000
Louisiana	540	---
Mississippi	1,420	1,000
Missouri	260	---
Nevada	1.3	---
New Mexico	118	---
North Carolina	80	6,000
Oklahoma	470	---
South Carolina	170	---
Tennessee	330	---
Texas	5,900	---
Virginia	.8	---
	12,704.4	24,060

a/ (24, 60, 131, 173, 182, 214, 222).

desirable for cotton producers to shift nematicide usage to EDB. DBCP is no longer produced in the United States. Distributors currently have only one foreign source of DBCP.

ALTERNATIVES TO EDB

Chemical Controls

The following materials and rates of application have been registered for control of nematodes on cotton. D-D (a mixture of 1,3 dichloropropene, 1,2, dichloropropane and related C_3 hydrocarbons weighing 10 pounds per gallon) applied at 180 to 250 pounds per acre overall or 75 to 100 pounds per acre in the row 10 to 14 days before planting. Telone II (92 percent 1,3, dichloropropene, weighing 10 pounds per gallon) applied at 90 to 150 pounds per acre overall or 45 to 60 pounds per acre in the row 10 to 14 days before planting. Nemacur applied at 1.65 to 3.3 pounds a.i./acre (on 40-inch rows) as a 15 percent granular formulation in 12 to 18 inch bands ahead of the planter shoe. Temik, 15 percent granular, applied at 2.1 to 4.05 pounds a.i./acre (40 inch rows) in the Far West, or 0.525 to 1.5 pounds a.i./acre (40 inch row) in other regions. Granules are drilled just below seed line at planting. DBCP (1,2 dibromo 3 chloropropane) 12.1 pounds per gallon applied at 17 to 26 pounds overall, 9 to 18 pounds in-row at planting or preplant. Terr-O-Cide 72-27 (EDB + chloropicrin) 1-2 gallons/acre row, 4.25 gallon/acre broadcast. EDB, D-D, Telone II and DBCP are all effective nematicides against the cotton root-knot nematode under ideal conditions for soil fumigation; however, these conditions seldom prevail or do so for only a short time. Under less than desirable conditions, particularly

lower or higher temperatures, DBCP, because of its vapor pressure, is the nematicide of choice (164).

In tests for control of the sting, lance, and reniform nematodes, applications of Nemacur and Temik have resulted in yields equal to those obtained with EDB, Telone II, D-D, and DBCP (20, 29, 30, 95, 223, 291).

The use of organophosphate and oxime compounds as nematicides on cotton may, however, reduce predacious and parasitic arthropods which provide natural control of several insect pests (115).

Cultural Practices

Crop rotations of one or more years are effective in reducing populations of the cotton root-knot nematode. In the western States alfalfa and some grain crops are used for this purpose. In Texas grain sorghum is alternated with cotton to control both root-knot and reniform nematodes. In the Delta and in the Southeast, soybeans are rotated. Where practical these rotations are employed effectively but in most instances they present the grower with unfavorable economic choices (79, 81, 176).

Varietal resistance to the *Fusarium* Wilt - cotton root-knot nematode complex exists in a number of named varieties and breeding lines of cotton. These include Auburn 56, DPL 45, DPL 25, and others (79). These show good yields in the presence of the *Fusarium* Wilt - nematode complex but high yielding, high quality cotton varieties with good resistance are not available (107).

Summer fallow will effectively reduce populations of root-knot nematodes in the West and Southwest. The land should be free of plant growth for 6 weeks to 2 months in the middle of the summer. In addition the soil should be turned

or ridged two or more times to permit drying. The practice is objectionable to growers on economic grounds from the expenditures in discing and listing, wind erosion, and from the loss of productivity (176). Soil fumigation enables the grower to utilize his investment more efficiently, minimizes soil erosion, and reduces dust problems.

Subsoiling by "hipper-ripper" for the control of damage caused by *Hoplolaimus columbus* in Georgia and South Carolina has resulted in yield increases equivalent to soil fumigation (95). However, it appears that this practice, while temporarily beneficial, only opens a reservoir of new soil for the cotton roots and permits temporary escape from the nematodes. After one or more years, the nematodes colonize this soil and soil fumigation must be resorted to.

Yield Losses due to Nematodes

In the opinion of a number of nematologists there are no adequate figures on yield losses due to nematodes. Estimates of the reduction in yield of cotton caused by diseases are compiled annually by the committee on disease losses of the Cotton Disease Council and are published in the Plant Disease Reporter (55, 175). These include losses due to root-knot and other nematodes. Losses have been as high as 2.93 percent of the national crop in 1973 and as low as 1.63 percent in 1966. The loss in 1976 represented 255,398 bales or 2.49 percent.

It is not considered that this loss includes the cost of nematode control needed to prevent other losses (175). From available evidence it appears that yield is approximately equal using EDB or its alternatives. The principal advantage to EDB would be in cost of the material and its availability.

Non-Target Effects

With the loss of EDB an increase of organophosphate and oxime compounds used as nematicides would be necessary. These chemicals have, at certain dosage rates, reduced the predacious and parasitic arthropods which provide natural control of several insect pests.

ECONOMIC ANALYSIS

This analysis was developed under the following assumptions and procedures.

1. EDB usage was estimated by the EDB Assessment Team.

2. Alternative nematicides and their usage rates were specified by the EDB Assessment Team. These alternatives were assumed to be most viable if EDB were not available. In making these determinations, product labels, State recommendations, efficacy of the alternative nematicides, and treatment costs per acre were considered.

3. Alternative nematicides would be available in sufficient quantities to replace EDB on cotton acreage.

4. The prices of alternative nematicides would not change.

5. Partial budgeting techniques were used to estimate the short-term impact of an EDB cancellation.

RESULTS

The annual increased cost of an EDB cancellation on cotton was estimated to be $435,700 (Table XIII-2). As total farm value of the cotton crop was $3.3 billion in 1975-1977, the loss of EDB would have an insignificant cost increase on cotton production. The per acre impact of $6.25 to $7.50 could, in the long run, force marginal producers out of cotton production. This could have

Table XIII-2 Economic evaluation of an EDB cancellation on cotton

Nematicide	Acres treated a/	Gallons applied per acre b/	Cost per acre c/	Cost of EDB applied	Cost of alternative applied	Net cost to agricultur
			dollars	- - - - - -	$1,000 - - - - - -	
EDB	35,560	2.5	13.75	765.3		
Alternatives to EDB						
D-D	13,474	8.5	21.25	—	286.3	
Talone	10,586	5.0	20.00	—	211.7	
DBCP	31,500	1.0	22.00		693.0	
Total						435.7

a/ Table XIII-1.

b/ Gallons applied per acre were estimated by the EDB Assessment Team based on state recommendations, efficacy of registered alternatives and their knowledge of nematode infestations.

c/ Based on farmer costs of $2.50 per gallon of D-D, $4.00 per gallon of Telone II and $5.50 per gallon of EDB, and $22.00 per gallon of DBCP.

significant local impact.

LIMITATIONS

1. It was assumed that there were no production losses when switching from EDB to an alternative fumigant. If significant production losses were to occur, individual producers could be faced with income reduction. The evidence generated in this study indicated significant production losses would not occur.

2. Information on EDB use was estimated by agricultural scientists rather than having been collected by survey. However, examination of information from several sources indicated that the Assessment Team's estimates were within the same range.

XIV. ANALYSIS OF EDB USE ON VEGETABLES

INTRODUCTION

EDB is registered for and used in significant quantities on the 13 vegetable crops listed in Table XIV-1. There are approximately 3 million acres planted to these crops annually with a production value of about $3 billion to the producers. These vegetables are produced on a significant commercial scale in 43 states (247). The major vegetable producing States are California, Texas, Florida, Idaho, New York and Washington. EDB is applied to vegetable fields in California, Florida, and Texas as well as Idaho and Washington. Small amounts are used in other States.

Pest Information

The major nematode pests are: Root-knot (*Meloidogyne* spp.); sting (*Belonolaimus* spp.); lesion (*Pratylenchus* spp.); stubby-root (*Trichodorus* spp.); stunt (*Tylenchorhynchus* spp.); and ring (*Macroposthonia* spp). Most vegetables and melons sustain greater nematode losses than any field crop.

Potatoes and sweet potatoes have additional pest problems which are controlled with EDB or EDB mixtures. In the Pacific northwest *Verticillium* wilt and nematodes are the primary pests. In Florida, wireworms and nematodes are potatoe pests. Sweet potatoes are attacked by root-knot nematode, sweet potato flea beetle (*Chaetocnema confinis* Crotch), and the southern potato wireworm (*Conoderus falli* Lane).

Table XIV -1. Production of selected vegetables

Crop	Acres Planted	Production	Value of Production
	1,000	1,000 cwt	$1,000
Broccoli	58	118,033	3,654
Carrots	75	19,176	129,398
Cauliflower	35	3,262	56,920
Cucumbers	78	24,726	136,494
Egg Plant	36	681	7,301
Lettuce	235	54,615	419,680
Lima Beans	66	1,507	24,110
Melons	341	38,016	222,560
Okra b/	9	1,620	14,580
Potatoes			
A. Washington & Idaho	920	214,598	903,806
B. Other States	484	141,527	364,430
Potaotes (sweet)	120	12,913	96,702
Squash b/	5	62	5,920
Strawberries	36	5,885	189,193
Tomatoes	497	23,978	415,661
Total	2,986	685,979	3,002,829

a/ These figures are 3 year average from "Vegetables, 1977 Annual Summary, Acreage, Yield, Production and Value, USDA, ESCS, Vg 2-2 (78), June 7, 1978.

b/ National figures were not available for these crops. Estimates were made by the EDB Assessment Team.

EDB Usage

It was estimated that about 180,000 acres of vegetables are treated annually with EDB (Table XIV-2). EDB is applied at rates of from 1.5 to 6 gallons per acre for the various vegetable crops. Based on application rates indicated in footnote a, Table XIV-3 and the acreage in Table XIV-2 an estimated 5.6 million pounds a.i. of EDB are used annually. The acres treated with EDB include those estimated to be treated with EDB as a result of the suspension of DBCP use on vegetable crops by EPA in 1977 (269).

EDB is applied as a liquid fumigant. For nematode control on vegetable crops, EDB is usually injected 8 inches deep into the soil through a series of chisels 12 inches apart or less commonly with a single chisel per row.

After application the soil is rolled or sometimes bedded. All applications are preplant and a two to three week waiting period is required. Dosage rates vary from 1.5-6 gallons per acre (18-72 lbs a.i./acre) broadcast. A rate of 4 gallons per acre would be an average application rate.

Alternatives to EDB

There are several registered alternatives to EDB for use on each vegetable crop. EDB is less expensive than the alternative soil fumigants which are available. The fumigants, D-D, Vorlex and Telone II perform

Table XIV -2. Distribution of EDB treated vegetable acreage among alternative nematicides, by crop

Crop	Acres treated with EDB a/	Acres treated with alternatives b/		
		D-D	Vorlex	Telone II
Broccoli	5,520	2,760	—	2,760
Carrots	15,400	9,240	—	6,160
Cauliflower	1,130	205	—	925
Cucumbers	21,870	8,748	8,748	4,374
Eggplant	500	365	90	45
Lettuce	500	300	—	200
Lima beans	30,000	15,000	—	15,000
Melons	35,880	23,508	—	12,372
Okra	6,413	4,182	1,396	835
Potatoes (white)				
A. Wash. & Idaho	10,000	4,000	—	6,000
B. Other States	9,900	4,950	—	4,950
Potatoes (sweet)	6,500	6,500	—	—
Squash	1,200	200	200	800
Strawberries	1,600	528	—	1,072
Tomatoes	34,000	17,000	—	17,000
Total	180,413	98,486	10,434	71,493

a/ Acres treated with EDB were estimated by the EDB Assessment Team using published data, when available, and their knowledge of EDB use patterns for the vegetable crops considered. The acres treated were those expected to be treated in the 1978 crop season and included those acres projected to be treated with EDB after the DBCP suspension on vegetable crops.

b/ The acres treated with alternatives to EDB were specified by the Assessment Team. In making these determinations, product labels, state recommendations, efficacy of the alternative nematicides, and treatment costs per acre were considered.

equally to EDB in all regions and crops except for potatoes in the Pacific Northwest. In the Pacific Northwest, nematodes and verticillium wilt require a multipurpose fumigant containing chloropicrin (Terr-O-Cide 54-45). Alternatives are D-D Pic (D-D with chloropicrin) and Telone C-17. The application rates for the nematicides used as alternatives to EDB are listed in the footnotes to Table XIV-3.

Crop rotation will not control all nematodes that injure vegetable crop plants because of the overlapping host susceptibility of economically productive cultivated and forage crops; therefore, crop rotation is of very little value in controlling nematodes on vegetable crops (102, 103, 215). Rotations that include poor-host or non-host plants can sometimes reduce the damage caused by nematodes, and where vegetables have a low per acre value, this may be the only economical method of control that can be used.

Plant breeders, working with nematologists, have developed 152 varieties for 23 major crops with resistance to one or more of 12 nematode species (81). In addition, there are 130 cultivars of six vegetable crops (common bean, lima bean, pepper, soybean, edible southern peas, and tomatoes) reported to be resistant to one or more species of root-knot nematodes but seed is generally not available. Most soils for vegetable production are infested with mixed communities of nematodes; therefore, the value of resistant varieties with monospecific resistance is minimal. More recently, data from greenhouse studies indicate that several cultivars of tomato previously reported to be resistant to root-knot nematodes (*M. incognita*), may not be resistant at all (60). "Resistance-breaking" races or pathotypes of nematodes are a

Table XIV -3. Alternative nematicides used to replace EDB on selected vegetables, cost of materials and changes in nematode control cost, by crop a/

Crop	With EDB	With alternative nematicides				Increase in nematode control costs	
		D-D	Vorlex	Telone II	Total	Total	Per Acre
	$1,000						
Broccoli	51	85	—	91	176	125	22.64
Carrots	381	285	—	202	487	106	6.88
Cauliflower	10	6	—	30	36	26	23.01
Cucumbers	201	269	420	143	832	631	28.85
Egg Plant	5	11	4	1	16	11	22.00
Lettuce	5	9	—	7	16	11	22.00
Lima Beans	248	462	—	492	954	706	23.57
Melons	330	724	—	406	1,130	800	23.11
Okra	59	129	67	27	223	164	25.57
Potatoes (white) b/							
A. Wash.&Idaho	990	510	—	648	1,158	168	16.80
B. Other States	91	152	—	122	274	183	18.48
Potatoes (sweet)	214	291	—	—	291	77	11.85
Squash	11	6	10	26	42	31	25.83
Strawberries	15	16	—	35	51	36	22.50
Tomatoes	312	524	—	558	1,082	770	22.65
Totals	2,923	3,479	501	2,788	6,768	3,845	—

a/ Application rates, material cost per gallon, and the alternative nematicides used were specified by the EDB Assessment Team based on product labels, State recommedations, efficiently of registered alternatives, and material costs per acre. The distribution of the EDB acreage treated with each alternative is presented in Table XIV -2. The application rates and material cost per gallon are as follows:

Current control program:
EDB: 1.5 gallons per acre for lima beans; 4.5 gallons per acre for carrots; 6 gallons per acre for sweet potatoes and 1.67 gallons per acre for the remaining vegetables (12 pounds a.i. at $5.50 per gallon).
Terr-O-Cide: (54-45) 6 gallons per acre (8.43 pounds EDB and 7.03 pounds chloropicrin) at $16.50 per gallon.

Alternative control program:
D-D: 16 gallons per acre for sweet potatoes, and 11 gallons per acre for remaining crops (10 pounds a.i.) at $2.80 per gallon.
Vorlex: 6 gallons per acre (11 pounds a.i.) at $8.00 per gallon.
Telone II: 6 gallons per acre for Irish potatoes and 8 gallons per acre for the remaining crops (10 pounds a.i.) at $4.10 per gallon.
DD-Pic: 22 gallons per acre (8.86 pounds DD and 1.57 pounds chloropicrin) at $5.80 per gallon.
Telone C-17: 15 gallons per acre (8.00 pounds 1-3 D and 1.8 pounds chloropicrin) at $7.20 per gallon.

b/ Terr-O-Cide 54-45 is used in Washington and Idaho and EBD in the other States. D-D-Pic (40 percent) and Telone C-17 (60 percent) are the alternatives in Washington and Idaho and D-D (50 percnet) and Telone II (50 percent) in the other States.

limitation to the continued usefulness of resistant varieties in vegetable (especially tomato) production areas. There are not sufficient varieties of resistant vegetable crops to off-set the great need for nematicides.

Summer and winter clean fallow are aids in controlling some nematodes (80). The best nematode control is obtained when clean fallow is maintained during hot, dry weather - either by withholding irrigation (which is only possible in arid areas) or by preventing plant growth by repeated plowing, harrowing, or use of nonselective herbicides (104). However, clean fallow depletes soil organic matter and enhances erosion (98). These methods do not provide an income for the grower. They do not provide adequate nematode control for commercial production of vegetable crops.

Flooding as a means of controlling root-knot nematodes was first reported in Florida by Watson (288). Later, studies by Thames and Stoner established that flooding of peat fields for three months gave practical control of *M. incognita* for two succeeding crops of vegetables (224). The elevation of most agricultural land in the United States does not permit the widespread use of flooding as a practical means of controlling nematodes on vegetable crops.

ECONOMIC ANALYSIS

The estimated short-run economic impact of an EDB cancellation on vegetables was based on the following assumptions and procedures.

1. EDB is applied once per year generally 10 to 14 days prior to planting.

2. Average U.S. 1975-1977 planted acreage was used as a base for the analysis.

3. Acreage treated with EDB was estimated by the EDB Assessment Team using available published data and their knowledge of EDB use patterns for the vegetable crops considered.

4. Alternative nematicides and application rates per acre were specified by the EDB Assessment Team based on product labels, State recommendations, efficacy of the alternative nematicides and treatment costs per acre.

5. Alternative nematicides were assumed to be as effective as EDB, based on published and unpublished data. Therefore, there would be no change in per acre vegetable production.

6. Alternatives would be available in sufficient quantities and their prices would not change.

7. Partial budgeting techniques were used to estimate the short-term impact of an EDB cancellation.

Results

The loss of EDB for use on vegetables would result in increased pest control costs to vegetable producers of $3.8 million (Table XIV-3). Pest control costs would increase because alternative fumigants cost more per acre. As stated previously, it was assumed that there would be no loss in vegetable production due to the cancellation of EDB. Given a producer value of these vegetables of about $3 billion, the increased costs would not have a significant impact on prices of these vegetables.

If a producer were applying EDB at 1.67 gallons per acre and had to shift to an alternative requiring 22 gallons per acre the increased handling costs would be significant and may exceed the increased pesticide costs. Producers in some regions may be applying EDB broadcast rather than in row. There was no information available to enable estimation of the number of acres treated broadcast.

A portion of the projected EDB usage in this study was based on acres treated with DBCP prior to the suspension of DBCP use on vegetables. Since the 1978 crop year was the first year of DBCP not being available, data was not available to verify the assumption.

These limitations could have a significant impact on the estimated impact on growers. However, the estimates provided in this report are the most likely impacts.

XV. ANALYSIS OF EDB USE ON HONEYCOMBS

INTRODUCTION

EDB is used to control the larvae of the greater wax moth (GWM) *Galleria mellonella* (L.), which damages the combs of the honeybee, *Apis mellifera* (L.). Honeybees are found in every State and where bees are found the GWM is present. It is more prevalent in the warmer regions and at lower elevations. To give an indication of the areas in the U.S. where bee culture is important, the following factors were examined: (a) the number of colonies; (b) yield per colony; (c) honey production, and (d) beeswax production (Table XV-1). Those States ranking in the top ten for at least three of these factors are identified in Figure XV-1.

Florida, California, and Texas account for 26 percent of the total U.S. production of honey, while Minnesota, North Dakota, South Dakota, and Wisconsin account for an additional 22 percent.

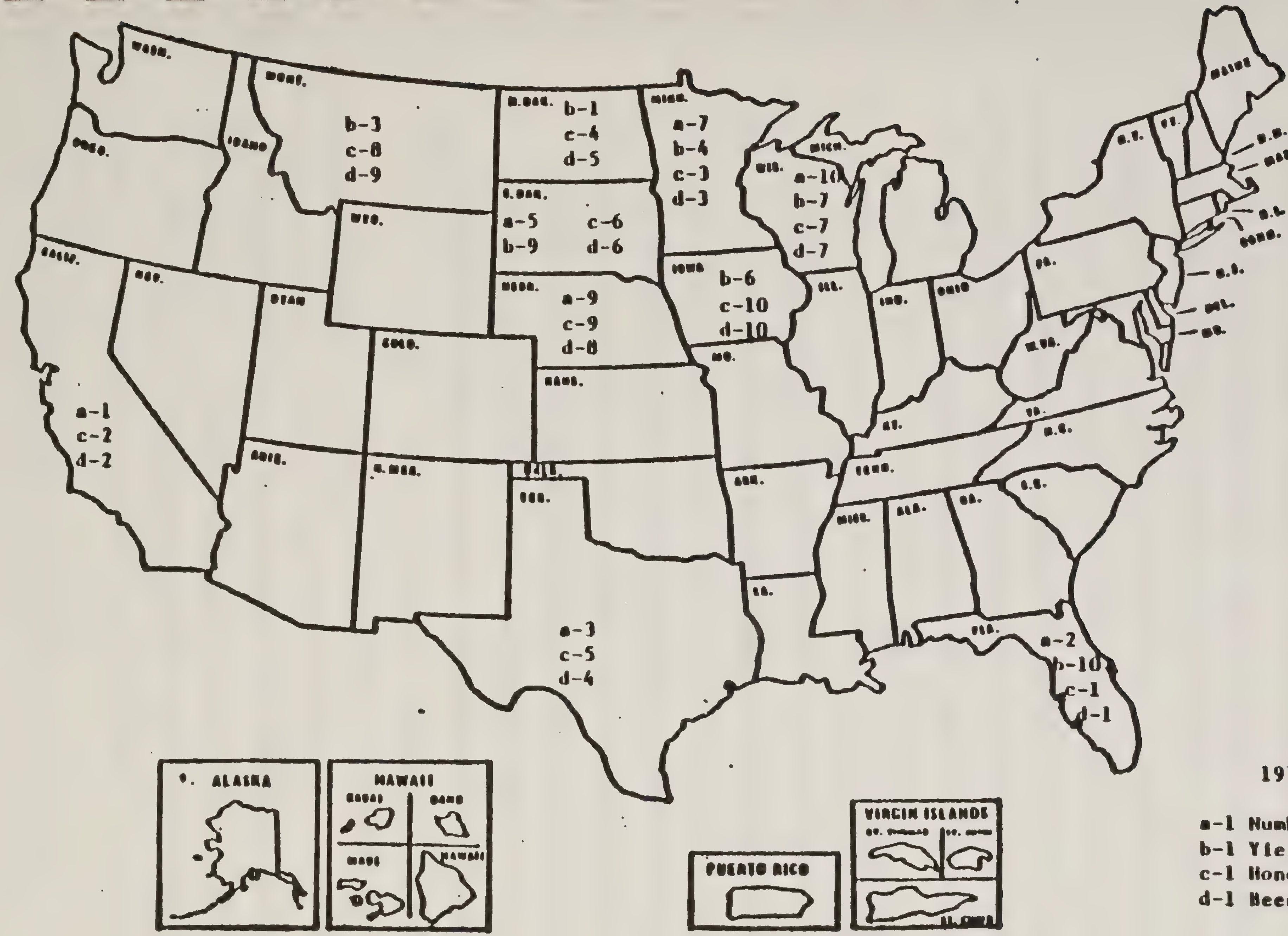
The longer growing season in the South and an agriculture that includes production of fruit, nut, seed, and nectar producing flowers enhance honey production. In the North Central States, the longer photoperiod and an agriculture that includes production of alfalfa and sweet clover seed, sunflowers, and native wild flowers along with winter bee killing explains high honey production in this region.

It has been established that pollination by honeybees contributes to the production of some crops, but the value of this pollination is open to wide speculation. Standifer (206) estimates that in the U.S. honey

Table XV-1. Honeybee : number of colonies, yield per colony and production of hon
beeswax top ten States ranked and U.S. three year average 1975-77 a/

State	Colonies				Production			
	Number	Rank	Yield	Rank	Honey	Rank	Beeswax	Rank
	1,000		lbs.		1,000 lbs.		1,000 lbs.	
California	517	1	-	-	17,267	2	320	2
Colorado	-	-	65	8	-	-	-	-
Florida	360	2	61	10	22,080	1	341	1
Georgia	147	8	-	-	-	-	-	-
Hawaii	-	-	90	2	-	2	-	-
Iowa	-	-	78	6	6,212	10	-	-
Michigan	-	-	-	-	-	-	85	10
Minnesota	148	7	84	4	12,387	3	214	3
Montana	-	-	88	3	7,504	8	134	9
Nebraska	139	9	-	-	7,012	9	136	8
North Carolina	203	4	-	-	-	-	-	-
North Dakota	-	-	101	1	11,653	4	168	5
South Dakota	158	5	62	9	9,829	6	156	6
Tennessee	155	6	-	-	-	-	-	-
Texas	206	3	-	-	10,442	5	182	4
Wisconsin	119	10	71	7	8,464	7	137	7
Wyoming	-	-	79	5	-	-	-	-
TOTAL	2,152		77.9		112,850		1,958	
Percent of U.S.	50.5		173.9		59.1		60.0	
U.S.	4,259		44.8		191,028		3,266	

a/ USDA, ESCS, CRB. Honey Preliminary 1977 Revised 1975-76. SeHy 1-3(78). January 17, 1978 (7).



1975-77

a-1 Number colonies
b-1 Yield per colony
c-1 Honey production
d-1 Beeswax productio

Top Ten States Ranked by Honey Bee Culture

Figure IV-1.

bees pollinate more than $1 billion worth of agricultural crops. The U.S. International Trade Commission (274) states "In 1975, it is estimated that the value of crops pollinated by bees was $8 billion". Mussen (144) states that "Pollination by honey bees was directly responsible for the production of nearly $3/4 billion worth of fruits, nuts, and vegetable crops in 1975 in California alone". It is difficult to assess the losses attributable to the GWM from the reduction in the number of colonies that affect pollination. Losses in pollination due to the GWM are unknown and substantiation is beyond the scope of this study.

Pest Information

During warm weather the adult moths lay eggs and upon hatching the larvae burrow into the combs. The larvae eat out the middle portion of the comb often completely destroying it. They leave tunnels and frass behind as they burrow through the comb. These tunnels are heavily lined with silken webbing and are easily seen when the combs are examined. The larvae are about an inch long when fully grown just before pupation. Heavy white cocoons are spun at the end of the frames and the larvae pupate in these cocoons. (302). Their damage renders the combs useless for beekeeping purposes.

The larvae of the GWM damage honeycombs in the hive in the apiary as well as honeycombs that are in storage between producing seasons. Honey bees control the GWM larvae in healthy hives. EDB is used to control the GWM larvae infesting the stored honeycombs. It is not used in hives that contain bees. When stored combs damaged by the GWM larvae are

returned to the hive, honeybees must devote time and effort to repairing the combs at the expense of producing honey and offspring. There could also be reduced pollination if the damages were severe over a longer time due to reduced numbers of bees in the hives.

EDB Usage

EDB is used to fumigate honeycombs that are to be stored between honey producing seasons. The storage period where the GWM is most prevalent is approximately four months.

83 percent EDB is generally used (12 lbs a.i./gallon). One to two tablespoons are applied to absorbent material atop eight stacked supers. 1/ This is equivalent to about 2 pounds/1000 cubic feet (121). The stack is then covered with an impervious cover such as polyethylene and fumigated for 24 hours.

The GWM frequently lays its eggs in the cracks between hive parts. EDB is effective against the eggs, larvae, and adults (234). EDB is largely used in the southern States where winter temperatures seldom get to the point of reducing the GWM populations by freezing.

The Assessment Team estimated that approximately 20,000 pounds of EDB are used annually to control the GWM (296).

Alternatives to EDB

Paradichlorobenzene (PDB) and carbon dioxide (CO_2) are registered alternatives to EDB. Although CO_2 is effective against all stages of the GWM, it requires a gas tight storage chamber and requires elaborate monitoring equipment. As a result, it is seldom used by beekeepers. Phosphine is a

1/ Upper stories above the hive body. It is a box without cover or bottom that holds the frames (a set of holders to support honey comb).

newly labelled product not being used or currently recommended. Bee experts contacted have no experience with this chemical. Therefore, it was not considered an alternative.

PDB is a crystalline substance that evaporates slowly. The honeycomb must be exposed continuously throughout the storage period to control the emerging larvae because PDB does not affect the egg. The continuity requirement is necessary so that when the eggs develop into larvae, a sufficient supply of PDB is available to control the new larvae. Three ounces, or 6 tablespoons, of PDB must be added each 2-3 week period. Roughly eight applications are estimated (192) to be needed for the complete storage period. Some larvae will hatch and damage the comb between applications. It was estimated that PDB is only 80 percent as effective as EDB (192).

ECONOMIC ANALYSIS

The estimated short-run economic impact of a cancellation of EDB use for controlling the GWM was based on the following assumptions and procedures:

1. The study area encompassed all States except Alaska. The GWM is not known to be a problem in Alaska.

2. EDB is used to control the GWM larvae on stored honeycombs and not on combs in the hive.

3. The alternatives to EDB as specified by the EDB Assessment Team are PDB (Paradichlorobenzene) and CO_2 (carbon dioxide). Only PDB was considered an alternative in the EDB economic analysis.

4. PDB is not as efficacious as EDB because it does not provide control during the egg stage of the insects life (192).

5. It was assumed that most commercial and sideliner producers in the southern States would use EDB. This accounts for about a third of the supers in the Nation. These would be treated once with EDB and 8 times with PDB on an annual basis (192).

6. Four standard supers were assumed to be used per colony--2 standard deep and 2 standard shallow with 10 frames per super.

7. Partial budgeting techniques were used to estimate the short-term impacts of an EDB cancellation; differences in cost of controlling the GWM, reduced honey production, and value of lost honey production were identified.

Treatment Costs

The use of PDB to replace EDB in the treatment of honeycombs to control the larvae of the GWM will increase beekeeping costs by about $3.7 million annually (Table XV-2). The cost per super treated will increase about 5 cents--4 cents with EDB and 9 cents with PDB. Further, with PDB there would be 7 additional treatments needed per super. The impact on an individual beekeeper is dependent on the number of supers previously treated with EDB.

Table XV-2. Economic impact of cancelling ethylene dibromide from use in controlling Greater Wax Moth larvae in the stored honeycombs.

Item	Honey bee colonies a/	Supers b/	Treated supers c/	Treatments d/	Super treatments	Material cost	Labor cost	Total treated cost	Total treatment cost e/
	-----------	1,000	-----------		1,000	-----	dollars per super	------	$1,000
EDB	4,259	17,036	5,679	1	5,679	0.00375 f/	0.03917 g/	0.04292	243.7
PDB	4,259	17,036	5,679	8	45,432	0.02400 h/	0.06250 i/	0.08650	3,929.9
Total	4,259	17,036	5,679	-	-	-	-	-	3,686.2

a/ From Table XV-1.
b/ Four Langstroth supers per colony (hive bodies) 2 Standard Deep, 2 Standard Shallow (10 Frame).
c/ Dr. H. Shimanuki estimates that probably one-third of all supers are treated with EDB, primarily in the Southern States.
d/ Each super is treated one time per year using EDB and eight times per year using PDB (2).
e/ Total treatment cost per super x number of supers treated.
f/ EDB cost of 3¢ per stack of eight supers or $0.00375 per super: personal communication Dr. H. Shimanuki (2).
g/ 15 minutes labor estimated for one treatment of EDB @ $7.50 per hour = $1.88 to treat 6 stacks of 8 supers ($1.88 ÷ 48 = $0.03917 per super). Dr. Shimanuki (2).
h/ PDB cost of 12 ¢ per stack of five supers or $0.02400 per super: personal communication Dr. H. Shimanuki (2).
i/ Two hours of labor estimated for 8 treatments of PDB @ $7.50 per hour = $15.00 to treat 8 (6 stacks of 5 supers) ($15.00 ÷ 240 supers = $0.06250 per super). Dr. Shimanuki (2).

Price Considerations

Economic theory proposes that as quantities supplied are reduced, other things being equal, price will tend to rise. In the short-run, domestic production of honey would decline causing upward pressure on domestic prices. Inventory stocks would be drawn down and imports would be stimulated. USITC (U.S. International Trade Commission) estimated that the elasticity of demand for foreign honey in response to domestic price change was 4.46 (274).

Generally, domestic honey producers' responsiveness to price is somewhat similar to producers of other food products in that the quantity produced cannot be easily expanded or contracted in response to changes in price in the short-run. Colonies can be divided and packaged bees purchased but these adjustments in production capacity take time. Generally, production changes are in response to the previous season's price change. Within a year, domestic producers response to price would be relatively inelastic, however, foreign producers could be more responsive by diverting exports from other countries to the United States. Since this analysis is for a short-run period (2-3 years) producers response could conceivably be more elastic after the first year in which prices rose as a result of a decline in the quantity of marketable honey.

Over the past several years, particularly since 1973, domestic honey production has trended downward (Table XV-3, Figure XV-2). Imports during the same period have increased while stocks on hand have remained fairly stable. Domestic utilization has been fairly stable at 1.1 pounds per capita during the 1967-77 period.

Table XV-3. Honey: supply and utilization U.S. calendar years 1967-77 a/

Year	Supply				Utilization		Domestic disappearance d/	
	Production	Carryin b/	Imports	Total supply	Carryout c/	Exports	Total	Per capita
	million lbs.							lbs
1967 e/	215.8	55.3	16.8	287.9	56.7	11.7	219.5	1.1[illegible]
1968 e/	191.4	56.7	16.9	265.0	41.0	8.1	215.9	1.[illegible]
1969 e/	267.5	41.0	14.7	323.2	62.7	9.9	250.6	1.2[illegible]
1970 e/	221.8	62.7	8.9	293.4	50.6	8.1	234.7	1.15
1971	197.4	50.6	11.4	259.4	30.9	7.6	220.9	1.0[illegible]
1972	214.1	30.9	39.0	284.0	29.8	4.1	250.1	1.2[illegible]
1973	237.7	29.8	10.7	278.2	37.7	17.6	222.9	1.06
1974	185.1	37.7	26.0	248.8	33.7	4.6	210.5	0.9[illegible]
1975	197.9	33.7	46.4	278.0	33.0	4.0	241.0	1.1[illegible]
1976	198.7	33.0	66.5	298.2	34.4	4.7	259.1	1.20
1977	176.4 f/	34.4	65.0	275.8 f/	29.9	5.5	240.4 f/	1.1[illegible]
Average	191.0	33.7	59.3	284.0	32.4	4.7	246.9	1.1[illegible]

a/ USDA-ESCS-CED, Sugar and Sweetener Report.
b/ Stocks on hand at beginning of the year.
c/ Stocks on hand at end of the year.
d/ Derived using military and civilian population from 1977 statistical abstract (8).
e/ Personal communication Harry Sullivan, USDA, ASCS.
f/ Revised.

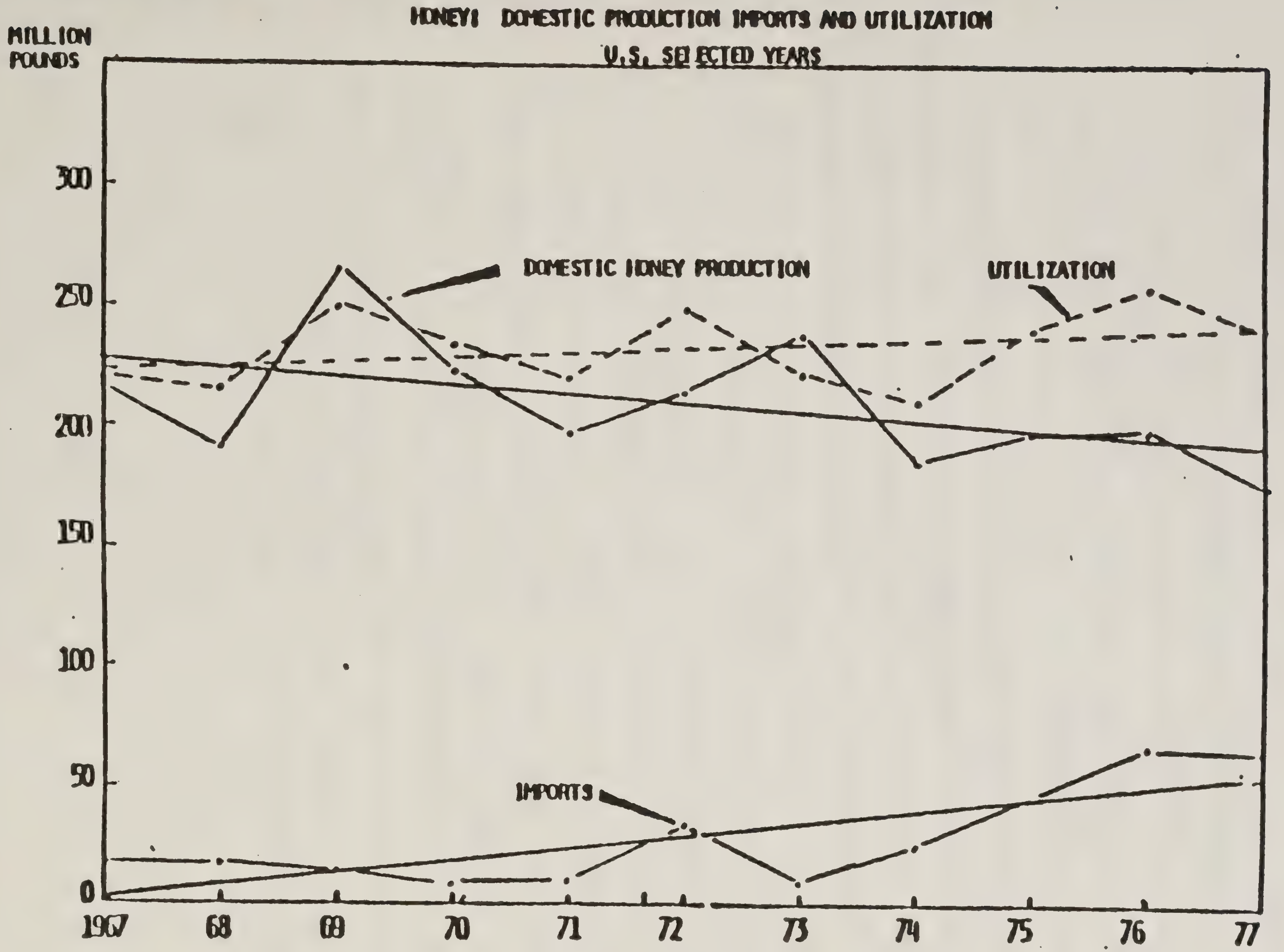

HONEY: DOMESTIC PRODUCTION IMPORTS AND UTILIZATION
U.S. SELECTED YEARS
MILLION POUNDS
300
250
200
150
100
50
0
1967
68
69
70
71
72
73
74
75
76
77
DOMESTIC HONEY PRODUCTION
UTILIZATION
IMPORTS

Figure XV-2.

Value of Lost Output

It was estimated that marketable honey will be reduced 20 percent in the supers previously treated with EDB as a result of using the next best alternative, PDB, to control the GWM larvae (192). This is due to decreased control of the larvae which damage the honeycomb requiring the bees to build new combs rather than produce honey. The Team further estimated that approximately one-third of all supers in the nation would be treated for the GWM using PDB in place of EDB. The total quantity of domestic honey would thus be reduced by 6.67 percent.

Honey production during 1975-77 averaged 191 million pounds (Table XV-1). Based on a 6.67 percent reduction in honey production without EDB, the total loss to beekeepers would be 12.7 million pounds. The 1975-77 average price per pound for honey was 51.2 cents (245). In the short-run, honey prices might increase as a result of an EDB cancellation due to smaller production but the effect would be dampened by drawing down inventory stocks and increasing inputs. For this analysis, it was assumed that honey prices would remain stable so the loss in honey production was valued at 51.2 cents per pound. The 12.7 million pounds of lost honey production would reduce beekeepers income by $6.5 million. It is reasonable to expect that the price of honey would increase as a result of a reduction in the quantity produced. Elasticity estimates for honey were not available to determine how much increases in honey prices might reduce the economic impact.

Summary

The economic impact of the cancellation of the registration of ethylene dibromide for use in controlling the Greater Wax Moth in honeycombs is estimated to be $10.2 million. Component parts of that impact are:

1.	Increased treatment costs	$3,686,000
2.	Reduction in total product value	$6,500,000
	Total	$10,186,000

Variable costs of treatment would increase from $244,000 to $3,930,000. Marketable honey would decline by 12.7 million pounds at $0.512 per pound or $6.5 million as a result of using the next best alternative, paradichlorobenzene (PDB) to replace EDB.

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